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eedom from Hunger Campaign

BASIC
Nº 10
STUDY

POSSIBILITIES OF INCREASING WORLD FOOD PRODUCTION

FOOD AND AGRICULTURE ORGANIZATION OF THE UNITED NATIONS - ROME - ITALY

FREEDOM FROM HUNGER CAMPAIGN

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POSSIBILITIES OF INCREASING WORLD FOOD PRODUCTION

With the Compliments of the
FAO INTERNATIONAL FOOD TECHNOLOGY TRAINING CENTRE
AT THE
CENTRAL FOOD TECHNOLOGICAL RESEARCH INSTITUTE
MYSORE CITY
INDIA

POSSIBILITIES OF INCREASING WORLD FOOD PRODUCTION

WALTER H. PAWLEY
Director, Program Formulation
and Budget Division, FAO

FOOD AND AGRICULTURE ORGANIZATION
OF THE UNITED NATIONS Rome 1963

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FOREWORD

The first half of the twentieth century has witnessed three major revolutions. The political revolution has given self-government to nearly a third of the world's population and has brought their aspirations for a better life to the forefront of world attention. The revolution in communications has broken down the barriers of distance and language, and the dynamism of ideas can no longer be contained within the limits dictated by social privilege or political considerations. The demographic revolution has imparted to the challenge of poverty and want a new dimension.

It is against this background that the Freedom from Hunger Campaign was launched in 1960 by the Food and Agriculture Organization of the United Nations. Its main objectives are twofold: first, to create a worldwide awareness of the problems of hunger and malnutrition which afflict more than a half of the world's population and which, apart from the human suffering and human degradation that they involve, pose a serious threat to peace and orderly progress, and second, to promote a climate of opinion in which solutions to these problems can be organized both on a national and on an international basis.

In the short time since its launching, the Campaign has already provided a focus for co-operative endeavor for international organizations, national governments, nongovernmental organizations and various citizens' groups all over the world. The 104 Member Nations attending the biennial session of the FAO Conference in November 1961 paid unanimous tribute to the significance of this Campaign for the future well-being of the world.

The Freedom from Hunger Campaign attempts to attack the problem of hunger on a broad front and at all levels of economic and social thought and action; but for practical purposes, it defines three sectors of operation: (a) *information and education,* (b) *research, and* (c) *action.*

The information and education sector will help bring to citizens everywhere a living awareness of the concrete facts and issues, and provide bases for deciding what new national and international policies and action programs are needed. This effort to create informed and active awareness will rise to a climax with the World Food Congress to be held under FAO auspices in 1963. Many international professional and citizens' groups will hold forums on Campaign issues in 1963. Many national Campaign Committees will also organize similar discussions. Representatives from all these bodies are expected to participate in the World Food Congress and help bring into focus policies and action plans for the future.

The series of **Basic Studies** *has been prepared by FAO and other co-operating international organizations to aid citizens in discussing the great issues involved.*

These documents attempt to summarize the known facts and agreed conclusions of experts in each special field, and thus provide useful and reliable background material for study groups and public discussions.

The volumes in this series cover broad subjects such as the adequacy of food levels in the world, the possibilities of producing more food, and the ways in which economic development and training in the newly developing countries can raise buying power and thus help hungry people to buy more food for themselves. They bring out the central importance of good nutrition for health and working efficiency, and study how people can learn to choose their foods better. They appraise the efforts being made in individual countries to raise food output, to increase jobs and incomes, and to train and educate people in ways to increase production and in better dietary habits. The volumes cover the relation of food production to climate and weather, the better distribution and marketing of food, and the use of available surpluses to relieve hunger and provide an incentive to economic and social development in the developing countries.

I trust that these **Basic Studies** *will stimulate thought and action on the critical problem of hunger and contribute to an ever-expanding understanding of the related social, economic and technical issues.*

B. R. SEN
Director-General

This particular study is directed toward a very specific question: Are the land and water resources of the world, if properly used, capable of providing an adequate level of nutrition to the population which is already foreseeable? This is a question of great public concern. Many answers are being given from many sources, some optimistic, some pessimistic, and there exists a great deal of confusion in the public mind on this issue.

Here FAO attempts to provide as factual and impartial an answer as existing information permits. The answer is based on the accumulated results of a decade and a half of experience in collecting information, making studies and working with Member Governments over the greater part of the world to improve production and nutrition. A tremendous amount has still to be learned about the world's agricultural and fisheries resources, but it was thought that a balanced attempt, on the part of the international organization charged with responsibility in the field of food and agriculture, to set forth the corpus of knowledge so far available and relate it to future needs, would make a worth-while contribution to public discussion of this issue.

It should be clearly understood that concentration on the technical possibility of meeting future food needs — naturally at economic levels — does not in any way imply an undervaluation of the enormous problems to be faced in realizing these possibilities. No one can be more acutely aware than FAO, after 15 years of practical experience in helping some 80 member countries in 5 continents, of the magnitude and complexity of the institutional, cultural, financial and political problems involved. This document does not, however, attempt to study these questions which have been examined in other publications in this series.

The present study, then, is based on the idea that the interested public is entitled to an answer as to whether, or to what extent, it would be possible to produce the food needed if mankind has the will and the courage to mobilize its resources of nature and knowledge toward this end. The answer to this question should itself help in providing the inducement to undertake this task.

The problem of population *versus* the food supply has tantalized the world for over 150 years since Malthus published his essay on the principle of population as it affects the future improvement of society (1798). Today, probably more people are thinking about it than at any other time during this period. It has become one of the principal issues of our day. It is the reason for the Freedom from Hunger Campaign.

Posing the issues

The subject may be posed in several ways. The classical exposition, that of Malthus, consists in comparing possible rates of growth of population and food production and inquiring whether the latter may be able to keep pace with the former. With the growing complexity of human affairs, it becomes ever clearer that the rate at which food production increases does not depend solely on the bounty of nature and man's technical ability to exploit it; economic, social, cultural and political factors account for a widening gap between knowledge and application, as well as exercising a major influence on the rate of accumulation of knowledge. To quote only one instance, the inability of people to pay for products that they desire and need physiologically has again become one of the major obstacles to production. The fact is that the popular question : " Will food production be able to keep pace with population growth?, " does not admit of a scientific answer, no matter how detailed the analysis. The factors involved are too numerous, too incalculable. Who can say what will be the position a generation from now, or in 1970, or even next year? The present study therefore eschews entirely the question of what *will* happen. Apart from the unpredictable nature of so many of the factors

involved, most of them lie outside the sphere in which FAO and its staff can claim any special competence.

A second issue of debate concerns the capacity of the resources of land and climate to support the rapidly increasing world population. Here we have a technical question: Is the extent of the usable land surface, and are the yields which the soil is capable of giving, considering limitations of fertility, rainfall and temperature, such as to provide adequately for the much higher population already foreseeable, even if the best use be made of their potentialities? The question may even be, and is asked, whether in fact these resources, allied with current technological knowledge, could provide an optimum diet for the present population of 3,000 million people. Some, dazzled by the amazing achievements of science, place little limit on the possibilities of continual increase; others, noting that the areas of easy expansion had already been taken up by the early years of this century and observing the exploitive nature of much of our present land use, with erosion and loss of soil fertility, fear for the maintenance of current levels of output rather than hope for an increase. The present study is directed entirely toward this more limited question of resource potentials.

It is evident that no final answer can ever be given as to the capacity of the lands of the earth. Even if good information were available, today's answer would not be the answer of tomorrow when resources, the concept of which is meaningful only in relation to knowledge and wants, will be different. Apart from the dynamic nature of the concept, information on agricultural potentialities is far too limited to attempt any final assessment of production possibilities.

Nevertheless, such information has increased in recent years. In particular, the upsurge of interest on the part of governments in the development of their agricultural resources, the volume of technical and preinvestment aid being given by FAO under the United Nations Expanded Program of Technical Assistance and the United Nations Special Fund program, and the work done under the Colombo Plan and the United States and other bilateral programs have begun to bring into sharper focus both the possibilities and the difficulties. Enough is perhaps known to justify a reappraisal of some of the resource potentials for increasing agricultural production under conditions that are economically feasible and pay due regard to the mainte-

nance of fertility. One of the results of the exploratory work of the postwar years, even though not directed at estimating over-all development possibilities, has certainly been to broaden the horizons regarding both the possibilities of producing more on the lands already in use and of bringing new lands under cultivation. At the same time, it has shown more clearly where the difficulties lie.

The fact that the study does not deal with the nontechnical factors affecting agricultural progress should not be taken as implying any undervaluation of their importance. Let it be said once and for all that truly enormous are the human, educational, sociological and institutional problems of bringing the necessary knowledge to each of the hundreds of millions of farmers and fishermen who, in the final analysis, are responsible for food production, each making his own managerial decisions and deciding on his own methods; or of remaking methods of production which are intimately tied to ways of living; or of overcoming the institutional and political resistances to bringing about these changes. Disease and malnutrition, lack of elementary education, ignorance, superstition and distrust of change, poverty often so absolute that it leaves the farm family nothing to invest in improvements and not daring to risk innovations, very small and fragmented holdings, adverse tenure relations, bad taxation systems, poor credit facilities, poor marketing and processing outlets, lack of domestic capital for investment in improved methods, political instability and sometimes even military turmoil, administrative inefficiency and corruption, shortage of trained personnel for technical leadership and administration and, above all, inadequate government services for agricultural research, education and extension — these are the difficulties of an underdeveloped country. This study does not dwell further on these basic issues, as they are the subject of another document and require more comprehensive treatment. It must, however, be stressed that the improvements mentioned in the following pages can be achieved only as the educational and institutional difficulties mentioned above are removed. On the other hand, these difficulties can best be tackled if we know where, geographically and technically, the main possibilities for increased production exist.

It would, of course, serve little purpose to consider the technical possibilities for increasing production without bearing in mind that many things which are technically feasible may be uneconomic. For

instance, it is necessary as a general rule to exclude from consideration those technical possibilities for raising yields per hectare or per animal which would clearly result in lowering the net productivity of the labor involved, either because they would be too labor-intensive or because they would otherwise involve an input of resources of greater value than the value of the extra output. Increases in production achieved in this way would result in the human race growing poorer. Man would be producing more food and other agricultural products only at the expense of other things. The objective of this study is rather to consider the possibilities for raising agricultural production within the framework of, and as part of, a rising standard of living. Most of the possibilities for raising yields discussed here would, in fact, have a tendency to lower costs of production rather than raise them, provided they are not pushed to extremes.

It should also be recognized that the future growth of knowledge and technology will not only increase technical possibilities but also render economically feasible things which are at present technically possible but unprofitable. For instance, with improved transportation, the cost of fertilizers is lowered, or power machinery reduces the cost of jungle clearance. Since this study is written from a long-range point of view, it is assumed, when speaking of the benefits which improved farming practices could bring in various parts of the world, that these are accompanied by the ancillary economic developments which would often be necessary to make them economically practicable. On the other hand, it is recognized that in some countries localized pressure of population on resources has led to methods which are so intensive in terms of labor input that they could not be recommended elsewhere, even though yields per unit of land area be very high.

Some policy implications of an appraisal of production potentials

Although the two issues are not always sufficiently distinguished, it is probable that neo-Malthusianism is rooted in a pessimistic belief regarding the possibilities of bringing new land into use and raising yields, rather than in a pessimistic view of the economic and social impediments to increasing production. Pessimism regarding the former underlies the fear that there is little hope of production keeping pace

with population at its present rate of growth, and it is for the same reason that recommendations for action are usually directed toward population rather than production.

The assessment of resource potentials is therefore basic for policy on the question of food and population. If the opportunities for expanding production are severely limited, a direct attack on the rate of population growth by any means possible is clearly a matter of desperate urgency, since an extremely large increase in production would be needed to feed and clothe adequately even the present population of the world. If, on the other hand, unused potentials are very great, there is a clear call to the nations of the world to reconsider the adequacy of the effort that mankind is devoting to the investigation and development of those resources; and, while a slower rate of population growth is obviously desirable, direct action on this front would be for the moment less urgent or at least it would be seen in a rather different perspective than is often the case in neo-Malthusian writings.

Contrary to the purely neo-Malthusian approach, it could be argued that the best prospects for achieving controlled fertility lie in economic development, involving both urbanization and a marked increase in agricultural productivity per hectare and per man. In other words, the main approach to the population side of the equation as well as the food supply side may lie in a sufficiently rapid rise in living standards. History suggests that an increase in the food supply in an *agricultural* society is almost invariably followed by a rapid increase in population, but it also offers the possibility that all-round economic development, resulting in opportunities for leisure and new concepts of living, create both the will and the understanding to adjust the family size to numbers which each family unit can support without unduly depressing its standards of consumption and leisure.

It is not to be overlooked that neo-Malthusianism is more than a belief about the future availability of food supplies in relation to population; it is frequently associated with an attitude of scepticism regarding the value, or even the desirability, of promoting increased food production or better health in underdeveloped regions. Such a belief, though held in all sincerity by many individuals, tends to serve as a theoretical or ideological basis for the social and political forces opposed, sometimes for selfish reasons, to a concerted effort to improve living conditions in the economically backward areas of the world.

It is clear, then, that the results of an assessment of physical resource potentials can have a major influence on *attitudes.*

Long-term assessment of resources in relation to future needs is also very important for setting agricultural and economic planning on the right road. It can reveal *where* the need for action is most urgent because the prospective pressure of population against basic agricultural resources may threaten a crisis on present evidence; or because the present methods of land and water use are doing permanent and major damage to the resources. It may often reveal that effective use of the potential resources will depend on far-reaching changes in the *patterns and methods* of resource use. In so doing, it can also indicate what are the patterns of land use toward which agricultural development needs to be directed to achieve the threefold objectives of conservation of the resources, full utilization, and orientation of production toward nutritional and market needs.

The following assessment of the capacity of the resources of land and climate at the disposal of man in the present stage of his technological knowledge is necessarily sketchy and of a preliminary nature. It is designed to stimulate the desire to know more, to give perhaps some broad indications of the lines along which future work might be directed, and to furnish a very provisional answer on the capacity of our resources in relation to foreseeable needs over the next four decades, which will take us to the historic milestone of 2000 A.D.

A more detailed assessment than is possible in this study, involving a careful appraisal over a number of years of existing knowledge region by region, associated with field surveys and experimental work where these are shown to be necessary, would make it possible to work out the most useful lines of attack both geographically and technically. It would in fact provide the over-all strategy for a world-wide policy of agricultural development.

1. MAGNITUDE OF THE FUTURE NEEDS FOR FOOD

A description of the nutritional situation in different countries and income groups is outside the scope of this document.[1] This section will attempt only to give the reader a very general idea of present deficiencies and the magnitude of the gap to be filled if diets are to be brought to a minimum satisfactory level.

The nutrition situation in the world today

Before we look at future requirements, we need to have clearly in our minds certain broad facts regarding the present nutritional situation in the world. We shall advisedly confine ourselves to one salient feature, namely, the striking contrast which exists between nutritional levels and nutritional patterns in what are described in Table 1 as Group I and Group II. Group I comprises the Far East, including Mainland China, the Near East, Africa, and by far the greater part of Latin America. Group II comprises those regions or subregions where the nutritional status of the population as a whole is fairly satisfactory. Specifically, it includes Europe, the U.S.S.R., North America north of the Rio Grande (United States and Canada), the so-called River Plate countries of Latin America (Argentina and Uruguay), and Oceania, which consists for the most part of Australia and New Zealand.

Looked at from the quantitative point of view, food consumption in Group II countries averages more than 3,000 calories a day, compared with an average of not much more than 2,000 calories in Group I countries. In this respect, as in others, there are of course some quite

[1] See FFHC Basic Study No. 11, *Third world food survey*. This section is partly based upon material used for this document.

1. Canada - 2. United States - 3. Mexico - 4. Cuba - 5. Jamaica - 6. Haiti - 7. Dominican Republic - 8. Puerto Rico - 9. Guatemala - 10. El Salvador - 11. Honduras - 12. Nicaragua - 13. Costa Rica - 14. Panama - 15. Colombia - 16. Venezuela - 17. Guianas - 18. Ecuador - 19. Peru - 20. Brazil - 21. Chile - 22. Bolivia - 23. Paraguay - 24. Uruguay - 25. Argentina - 26. Hawaii - 27. Ireland - 28. United Kingdom - 29. Denmark - 30. Norway - 31. Sweden - 32. Finland - 33. Netherlands - 34. Belgium - 35. France - 36. Spain - 37. Portugal - 38. Italy - 39. Sicily - 40. Sardinia - 41. Germany, Fed. Rep. - 42. Switzerland - 43. Austria - 44. Yugoslavia - 45. Germany, Eastern - 46. Poland - 47. Czechoslovakia - 48. Hungary - 49. Romania - 50. Bulgaria - 51. Albania - 52. Greece - 53. U.S.S.R. - 54. Turkey - 55. Syria - 56. Lebanon - 57. Israel - 58. Jordan - 59. Saudi Arabia - 60. Yemen - 61. Iraq - 62. Iran - 63. Afghanistan - 64. Pakistan - 65. India - 66. Ceylon - 67. Nepal - 68. China, Mainland - 69. Burma - 70. Thailand - 71. Laos - 72. Viet-Nam - 73. Cambodia - 74. Fed. of Malaya - 75. Singapore - 76. China, Taiwan - 77. Philippines - 78. Indonesia - 79. Australia - 80. New Zealand - 81. Korea - 82. Japan - 83. Morocco - 84. Algeria - 85. Tunisia - 86. Libya - 87. United Arab Rep. - 88. Mauritania - 89. Gambia - 90. Senegal - 91. Mali - 92. Upper Volta - 93. Niger - 94. Chad - 95. Sudan - 96. Ethiopia - 97. Somalia - 98. Guinea - 99. Sierra Leone - 100. Liberia - 101. Ivory Coast - 102. Ghana - 103. Togo - 104. Dahomey - 105. Nigeria - 106. Cameroon - 107. Central African Rep. - 108. Gabon - 109. Congo (Brazzaville) - 110. Congo (Leopoldville) - 111. Uganda - 112. Kenya. 113. Ruanda-Urundi - 114. Tanganyika - 115. Angola - 116. N. Rhodesia - 117. S. Rhodesia - 118. Nyasaland - 119. Mozambique - 120. Madagascar - 121. S. W. Africa - 122. Bechuanaland - Basutoland - Swaziland - 123. South Africa.

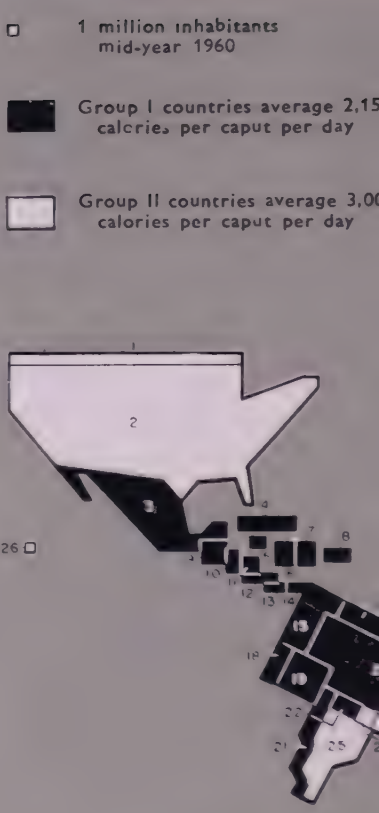

1 million inhabitants mid-year 1960
Group I countries average 2,15 calories per caput per day
Group II countries average 3,00 calories per caput per day
26

Chart 1. - NUTRITIONAL STATUS BY GROUPS

(Countries and territories shown in proportion to population)

TABLE 1. – CONTRASTS IN NUTRITIONAL STATUS BETWEEN ECONOMICALLY UNDERDEVELOPED AND ECONOMICALLY DEVELOPED REGIONS [1]

Item	Group I	Group II
Calories (per person per day)	2 150	3 060
Total protein (grams per person per day)	58	90
Animal protein (grams per person per day)	9	44
Population (1958) in millions	2 001	858

[1] Adapted from a lecture by P.V. Sukhatme, Director, Statistics Division, FAO, The world's hunger and future needs in food supplies. *The Journal of the Royal Statistical Society*, Series A (General), Vol. 124, p. 463-525.

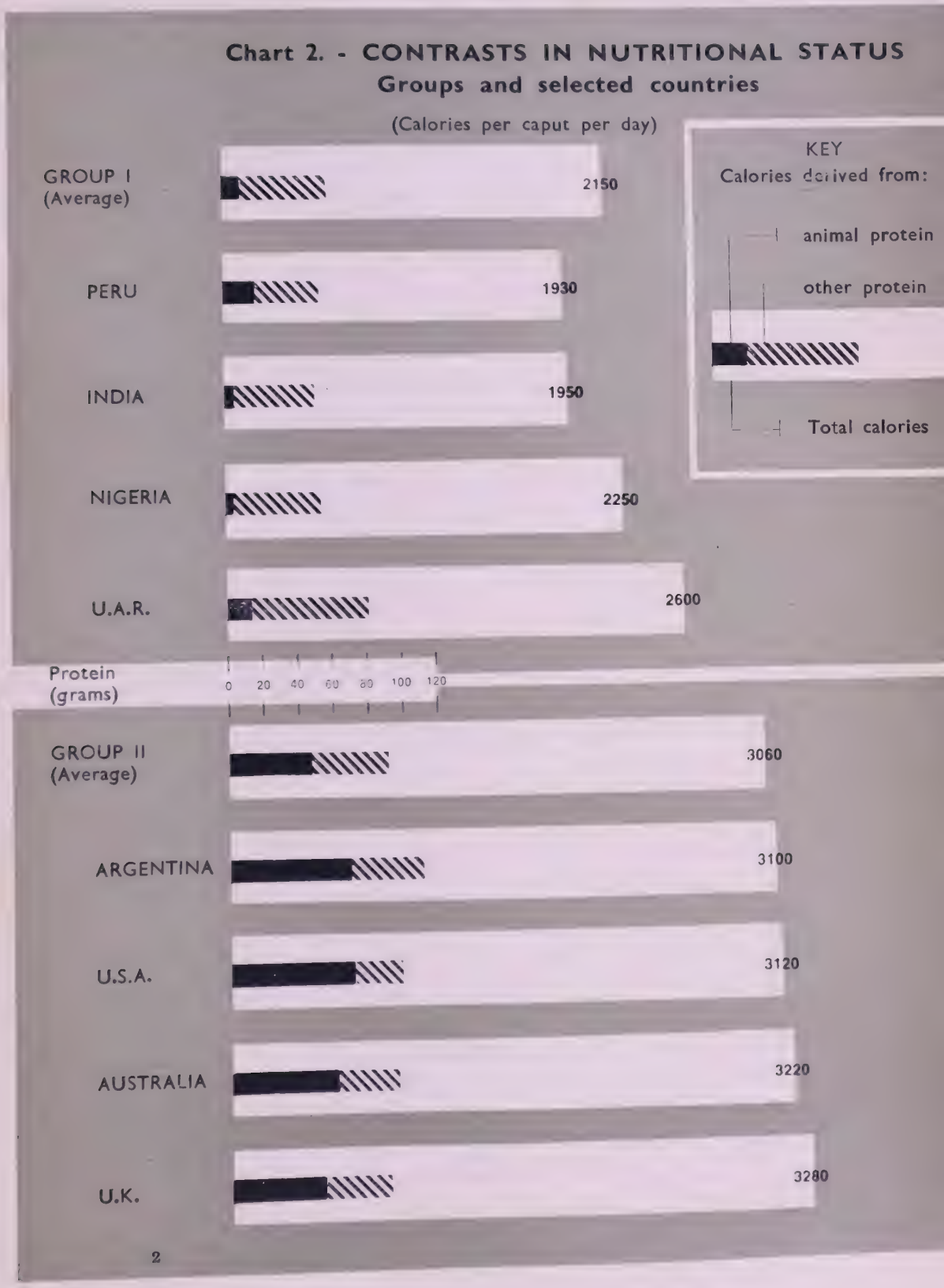
important differences from country to country, but it is not possible to go into them in this study, nor do they invalidate the soundness of the contrast shown here.

The most striking contrast, however, relates not to the quantity but to the quality of the diet, and this may be measured conveniently in terms of the amount of protein received from foods of animal origin. In Group II countries with an average protein intake of 90 grams per person per day, half is derived from foods of animal origin. In the countries belonging to Group I, the average intake of animal protein is only 9 grams, that is, one fifth of the average level of Group II countries. The characteristic of diets in underdeveloped countries is that they are composed mainly of very large quantities of cereals and starchy foods and that even where they are sufficient in quantity they are seriously deficient in quality.

There is therefore general agreement that the increase in calorie intake should not always be obtained from an increase in per caput consumption of cereals or starchy roots, which would still further unbalance the diet, but should come from those foods which would give a better balance to the present diet, namely, fruits, vegetables, pulses and nuts on the plant side, and still more important, the foods of animal origin — milk, meat, fish and eggs.[2]

[2] The problem of education as a means of increasing consumer demand for such foods of high nutritive value has been dealt with in FFHC Basic Study No. 6, *Education and training in nutrition.*

Chart 2. - CONTRASTS IN NUTRITIONAL STATUS
Groups and selected countries



To complete this bird's-eye view, one must look also at population. Seventy percent of the world's population is in the regions where undernutrition and malnutrition are prevalent. FAO estimates that up to half of the population of the world continues to suffer from undernutrition and malnutrition in varying degrees.

The race between food and population

In Table 1 we have a kind of photograph of the situation at a given time. Chart 3 on pages 18-19 presents the information at our disposal as a kind of film of a race – the race between population and food production. The varying fortunes in this race are depicted on the chart. In each case, the broken line shows the trend in food production and the solid black line the trend in population. These trends are shown over the last eight years for each of the main regions into which the world may be divided. The chart takes as its starting point the average level of food production in that particular region and in the world in the years immediately preceding the second world war. This may be illustrated by taking for a moment the graph which refers to the world as a whole.

By 1952 world population was 20 percent higher than before the second world war, while food production had increased slightly more, an increase of nearly 25 percent. The position was therefore some 3 or 4 percent better than it had been in the base period. Population is now about 35 percent higher than before the war, but food production has been increasing more rapidly than population and is now about 50 percent higher than before the war, with an improvement in the average position per person of more than 10 percent.

This seems rather encouraging until we look at the regional picture. Here we find some strong contrasts. In North America and in Europe, production has far outstripped the growth of population. In the underdeveloped regions, population and production are racing neck and neck.

When we take this regional viewpoint we see that for the most part it is precisely those regions which were already well fed before the war where food production has been racing ahead of population growth. The graph of Europe, for instance, shows food production 50 percent higher than before the war, against an increase in population of only

10 percent. In North America, production has risen about 65 percent, even though held back by lack of markets, compared with a population increase of 40 percent. The trends in the broken line for food production and the solid black line for population in these two regions explain why it is that surpluses are piling up. The situation for Oceania is something of an exception to the rule, but the course of food production in Oceania is largely a reflection of the piling up of surpluses in other exporting countries and the growing self-sufficiency in the traditional importing countries of Europe. There is no shortage of food in Australia and New Zealand, since they export about half of what they produce. The broken line for production would probably rapidly pass the population curve if it were possible to find adequate export outlets.

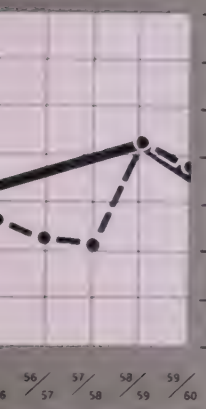
Let us now turn to the four underdeveloped regions. In Latin America, food production and population are indeed racing neck and neck. Between 1952 and 1956, the rate of increase of food production caught up with the rate of population increase, but in recent years the outcome is more doubtful. In the Near East, the prewar position had already been restored by 1952 and there were promising signs that real progress was being made. Latterly, however, the margin has narrowed again, so that per caput food production has declined somewhat since 1957/58. Africa is another region where there was cause for some optimism until 1956. It looked as though food production were edging, though very slightly, ahead of population. The results of the last three years give no cause for optimism.

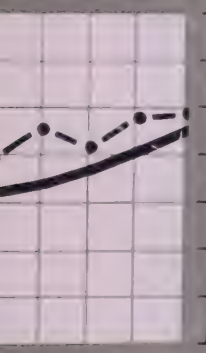
The Far East deserves special attention, not only because more than half the population of the world lives in the region but because the density of the population and, in general, the pressure on the natural resources and the low rate of capital accumulation account for the highest incidence of hunger and malnutrition. In this extremely important region, food production has barely made up the ground lost in the race with population during the war, and the position remains extremely serious, owing to the complete inadequacy of the present levels of food supply. Fortunately, there is some narrowing of the gap but the position still remains precarious. Though there are manifest problems of malnutrition and even sometimes of hunger in Africa, the Near East and parts of Latin America, it is in the Far East that the heart of the world food problem lies.

Chart 3. - THE RACE BETWEEN FOOD AND POPULATION

ndices, prewar = 100

EANIA

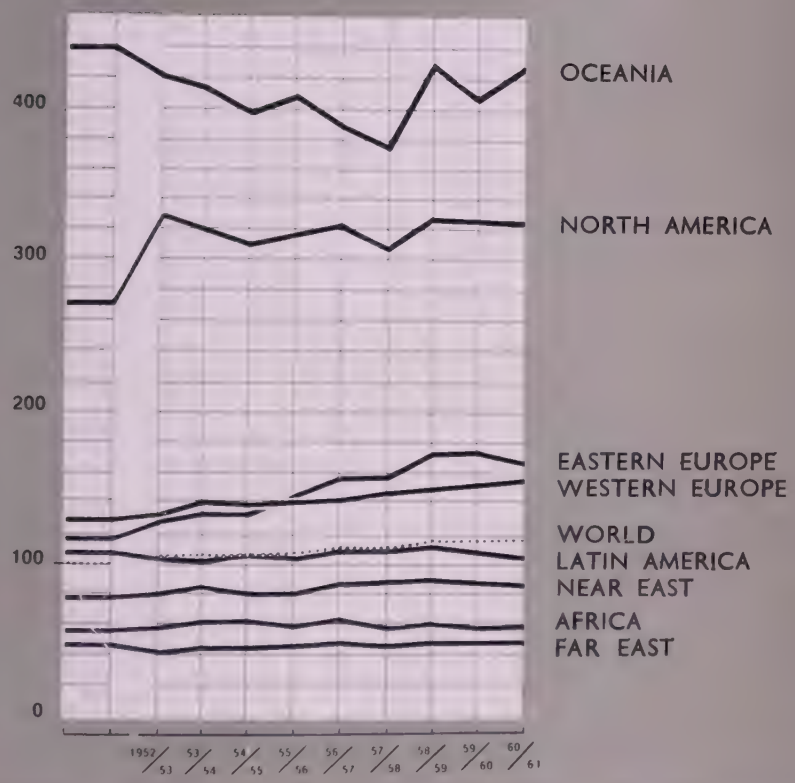




ICA

Trends of food production per head

(World average, prewar = 100)



From all this we can draw one important conclusion, namely, that the problem of food and population needs to be studied on a regional rather than a world basis. This is a point to which we shall return in the final section of the present document.

Future needs for food

We may now turn to the future. It is not enough to live from year to year. We need to take stock of the needs that can already be foreseen several decades ahead and of the possibilities of meeting these needs. To take the measure of the problem is a first and necessary step to adequate action.

The Population Division of the United Nations has made projections for population growth up to the year 2000, now only 37 years ahead of us. It provides a convenient date for a kind of future stock-taking. The population of the world passed the 3,000 million mark some time in 1961. By 2000, it appears likely that it will be in excess of 6,000 million. Naturally, somewhat different figures can be arrived at, depending on the assumptions made regarding the future course of birth and death rates. It is certain, however, that there will be a tremendous spurt in population during the next few decades. This applies particularly to underdeveloped regions, where postwar advances in medicine and sanitation have almost everywhere led to a sharp drop in the death rate, with a consequent increase in the gap between the birth and death rates. What this will mean in terms of regions is shown in Chart 4.

It is too early to say how long it will take before birth rates begin to come down and how rapidly they will fall. We have already been living for a decade and a half in the period of what is popularly known as the population explosion. So far, the rate of population increase is accelerating year by year and it may be that we are still only in the early stages of this period of explosion. It is also possible that within the next decade or two, that is, considerably before 2000, the economic, sociological and cultural changes which are beginning to transform Asia, Africa and Latin America will have begun to make their effect felt on the birth rate, and the rate of increase in population will begin to decelerate.

The rate of population growth provides us only with the first element in estimating future food requirements. If food production were to increase at only the same rate as population over this period, we should not be able to provide the rising generation and its children with the improvements in diet which have now become a part of the aspiration of hundreds of millions of people throughout the world. Progress in nutrition is essential for health and vitality but it is also an integral part of the so-called " revolution of rising expectations."

How much do dietary standards need to be improved in order to provide adequate nutrition?

During the 15 years of its existence, FAO has put much thought and detailed work into the measurement of per caput requirements which differ from one part of the world to the other, depending upon quite a number of factors, of which climate is an important one. In view of the fact that agreed standards on many nutrients are still lacking, it is customary to take into consideration three factors in arriving at desirable dietary standards. These are (*i*) total calorie intake ; (*ii*) total intake of protein; and (*iii*) its quality measured for convenience in terms of proteins of animal origin.

Fortunately, there is no need to reproduce the dietary patterns found in Group II countries in order to produce a diet which could be considered nutritionally adequate. In these regions, with an average calorie intake of over 3,000 per day, the problem is often one of overeating rather than undereating, though malnutrition is still to be found in certain social groups and in certain areas. A diet containing much meat and possibly certain other animal products would also probably not be acceptable in many parts of the world.

In any case, an objective of, say, 40 grams of protein of animal origin in the underdeveloped regions would require an increase of almost astronomical proportions in the value of agricultural production, especially when taken in conjunction with the projected rate of population growth. Animal foodstuffs are much more expensive than plant products in terms of the land and labor resources required to produce them, and therefore inevitably more expensive to the consumer. This means that the cost of achieving a satisfactory nutritional level is proportionately much greater than the required increase in calories. For instance, it has been estimated [3] that in the Far East

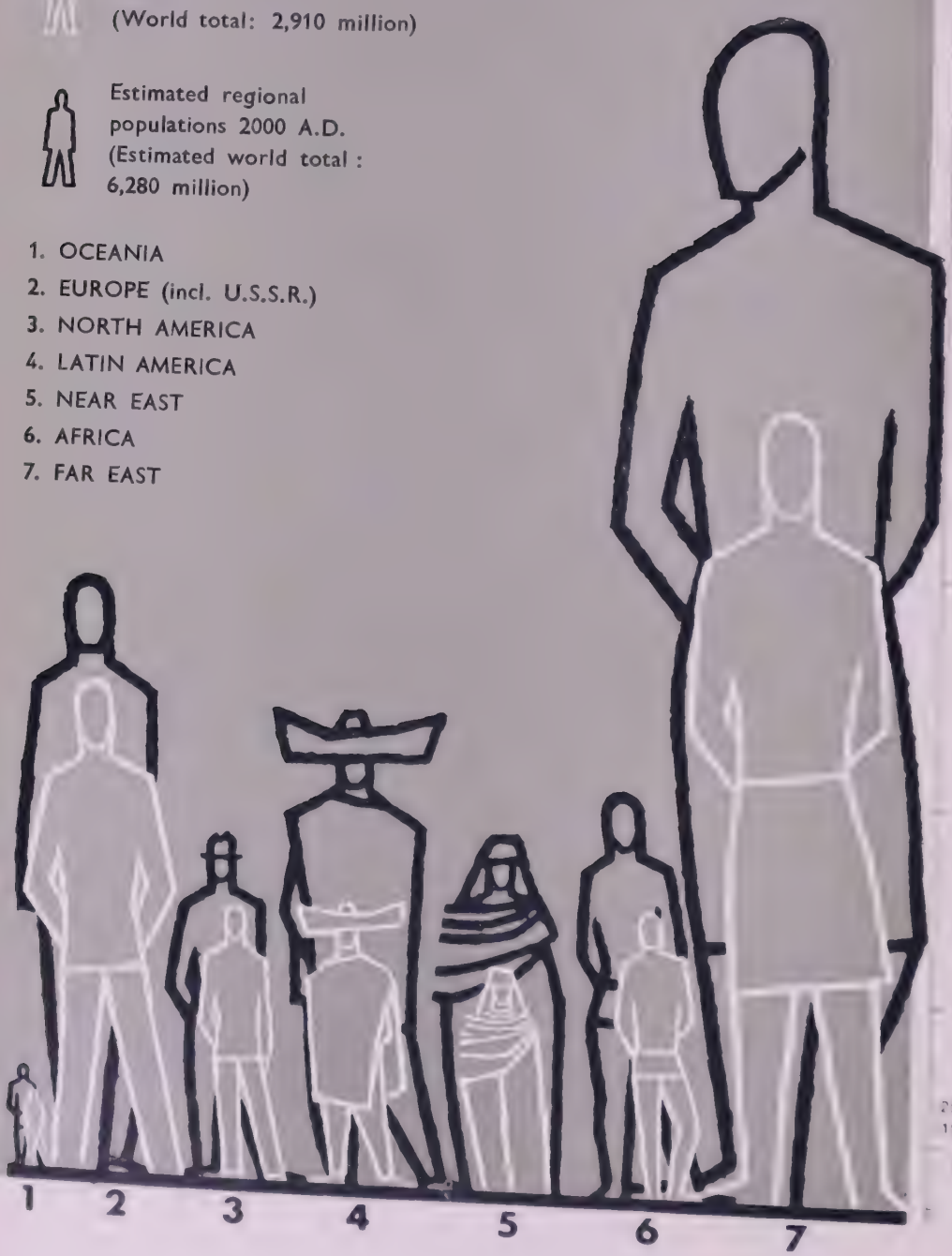
[3] P.V. Sukhatme, *Op. cit.* (see footnote 1 to Table 1).

Chart 4. - EXPECTED POPULATION GROWTH

Regional populations
1960
(World total: 2,910 million)

Estimated regional
populations 2000 A.D.
(Estimated world total :
6,280 million)

1. OCEANIA
2. EUROPE (incl. U.S.S.R.)
3. NORTH AMERICA
4. LATIN AMERICA
5. NEAR EAST
6. AFRICA
7. FAR EAST



a nutritional pattern which brought the average consumption of animal protein to 20 grams per day would bring about an improvement of about 16 percent in the calorie intake but would represent a 67 percent increase in the cost of the diet.

It is well known that the nutritional needs of different populations living and working under different conditions vary considerably. Moreover, there is still room for honest differences of opinion as to just what level of intakes, and especially of vegetable and animal protein, would be needed in various regions for good health. However, present thinking is that in most developing regions, a diet which does not consist mainly of a few staple starchy foods and provides, say, 2,400 calories per day, with an intake of animal protein of not less than 20 grams per day and a total protein intake of about 70 grams per day, would suffice. In particular, it must be remembered that a very large part of the population of underdeveloped regions lives in the tropics or subtropics, where the total calorie needs are lower than in cold climates, and that the needs for calories, protein and many of the other essential nutrients are interdependent.

In the face of uncertainties regarding population projections, minimum levels for adequate nutrition and, we might add, our information on present levels of food consumption in many countries, there is certainly no one definite answer concerning the additional quantities of food that would need to be produced by the year 2000 to provide at least a minimum nutritionally sound diet throughout the world. There does, however, exist a general consensus of opinion on the broad order of magnitude involved. In a recent estimate starting from an objective of 20 grams of animal protein, it has been calculated that by 2000 A.D. the supply of food would have to increase fourfold in Asia and the Far East, between three- and fourfold in Latin America, threefold in the Near East, and between two- and threefold in Africa.[4] The main elements in these estimates are set out in Table 2.

Until more detailed work has been carried out on present levels of food consumption and estimates of nutritional requirements in various parts of the world have been further refined, these estimates probably come about as close as we can go to putting a figure on the increase needed in food supplies in underdeveloped regions by

[4] P.V. Sukhatme, *Op. cit.*

2000 A.D. if present population projections turn out to be more or less correct. More detailed information on this aspect will be found in the FFHC Basic Study, *Third world food survey*.

There are, however, several reasons for believing that these figures should be taken rather as representing the lower limit of the increases that would be necessary to achieve the stated objective of providing around 2000 A.D. a diet of about 2,400 calories per day with 20 grams of animal protein in the developing regions.

The figures in Table 2 are primarily based upon national averages and thus ignore the fact that a proportion of the population already has a diet which exceeds the proposed level, while for the greater part of the population the deficiencies in diet, and particularly in animal protein, must be greater than indicated by the national averages.

TABLE 2. – ESTIMATED FOOD REQUIREMENTS *circa* 2000 A.D.[1]

A. Estimated food requirements — Asia and Far East

Item	Approximately 1958	By 2000
Calories (per person per day)	2 070	2 400
Vegetable protein (grams per person per day)	48	55
Animal protein (grams per person per day)	8	20
Index of consumption per person	100	167
Population in millions	1 498	3 639
Population index	100	243
Index of total food requirements	100	406

B. Estimated food requirements — Africa

Item	Approximately 1958	By 2000
Calories (per person per day)	2 360	2 450
Vegetable protein (grams per person per day)	50	48
Animal protein (grams per person per day)	11	20
Index of consumption per person	100	128
Population in millions	208	421
Population index	100	202
Index of total food requirements	100	259

[1] Adapted from a lecture by Dr. Sukhatme, Director, Statistics Division, FAO. The world's hunger and future needs in food supplies. *The Journal of the Royal Statistical Society*, Series A (General), Vol. 124, p. 463-525.

C. Estimated food requirements — Near East

Item	Approximately 1958	By 2000
Calories (per person per day)	2 470	2 470
Vegetable protein (grams per person per day)	62	57
Animal protein (grams per person per day)	14	20
Index of consumption per person	100	117
Population in millions	125	327
Population index	100	262
Index of total food requirements	100	307

D. Estimated food requirements — Latin America
(excluding River Plate countries)

Item	Approximately 1958	By 2000
Calories (per person per day)	2 370	2 400
Vegetable protein (grams per person per day)	42	42
Animal protein (grams per person per day)	19	20
Index of consumption per person	100	105
Population in millions	170	548
Population index	100	322
Index of total food requirements	100	338

Since we may assume that the well-fed people are hardly likely to reduce voluntarily the quality of their diet for the benefit of others, the index of consumption per person should certainly be somewhat higher. This probably applies to Latin America, where there exists quite a large middle and wealthy class, including foreigners as well as indigenous population, whose dietary habits have little in common with the millions of Indians and Mestizos who are found in the rural areas; and to Africa, where in certain areas of the Mediterranean littoral, in East Africa and in South Africa, there exist several million people of European origin, whose consumption of the higher-priced foods must weigh fairly heavily in the regional averages.

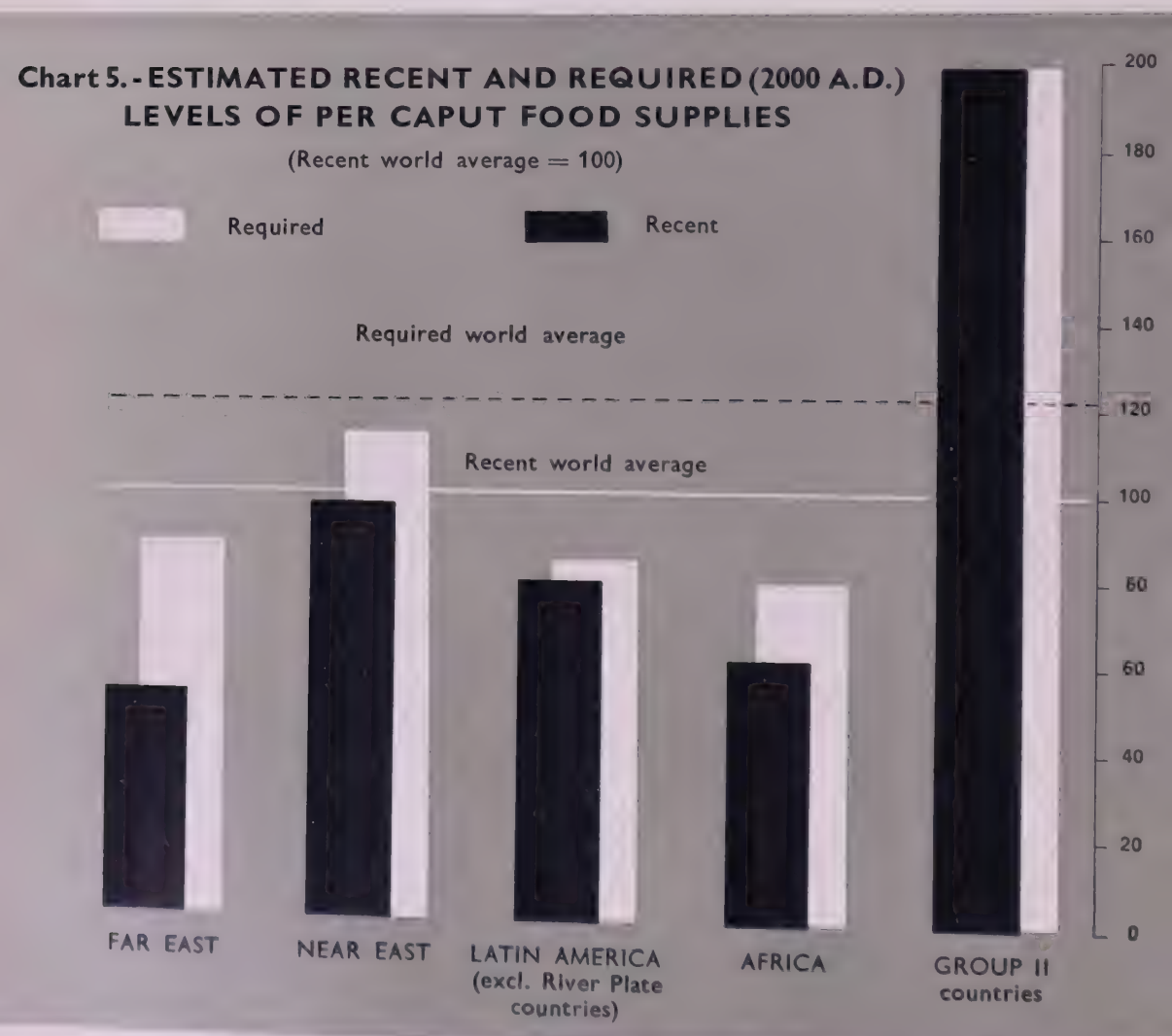
Secondly, the index is based upon a mathematical formula which assumes that consumers will act as completely rational beings in adjusting their tastes to a nutritional pattern which would be the cheapest way of reaching the targets for animal protein, etc. For instance,

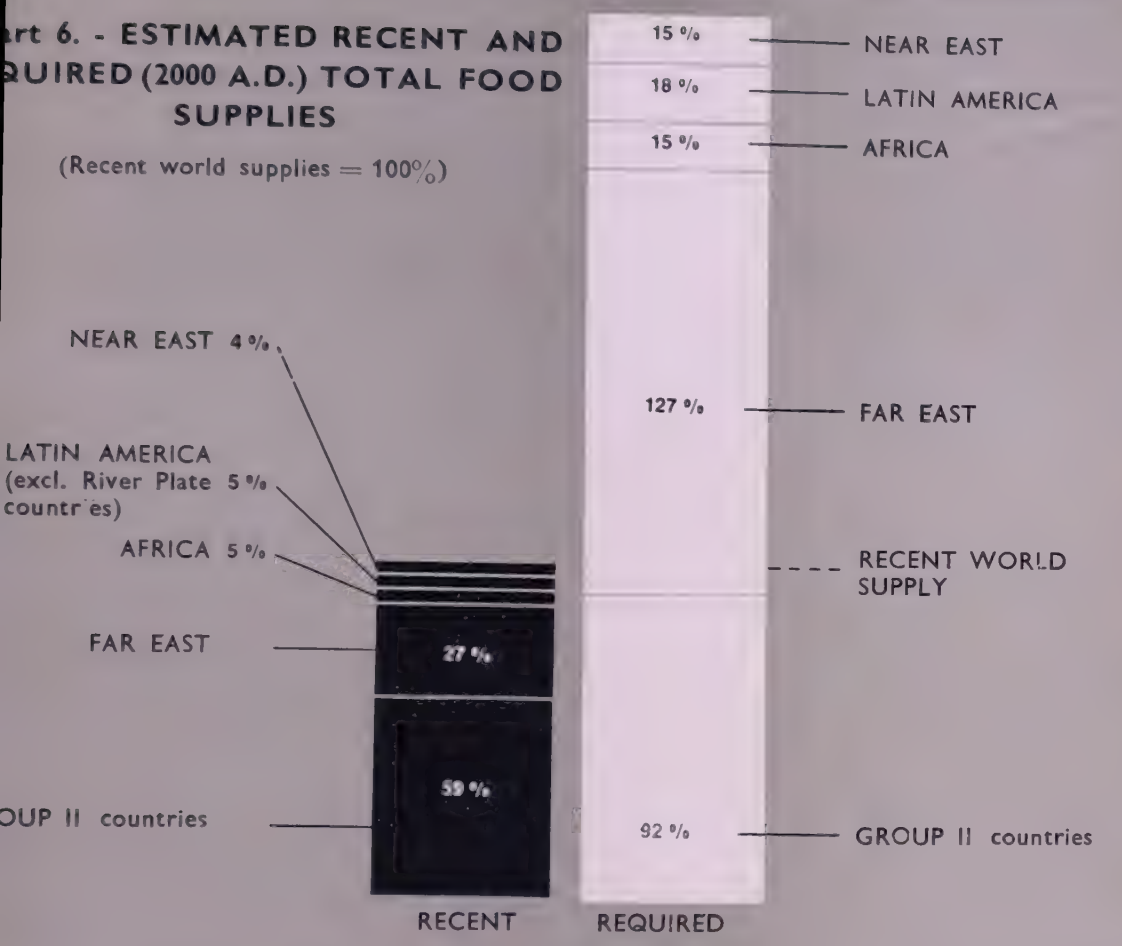
it is assumed that the consumption of fats and sugar in the year 2000, when per caput incomes would need to be perhaps three or four times higher to provide an effective demand for the proposed dietary pattern, would be practically the same as they are at present. It is hardly likely that consumers will willingly be so spartan. If they are not, the cost in terms of resources of providing 20 grams of animal protein may be rather higher.

There is also a comment to be made on the principal criterion, in terms of which the nutritional objective has been defined, namely, 20 grams of animal protein per person per day. In the Far East,

Chart 5. - ESTIMATED RECENT AND REQUIRED (2000 A.D.) LEVELS OF PER CAPUT FOOD SUPPLIES

(Recent world average = 100)





where consumers are used to a quite small quantity of animal foods in their diet, this might well satisfy consumer demand as well as meeting nutritional requirements. It is hardly likely to satisfy consumer demand in some regions, for example, Latin America, where, if the figures for present consumption are to be believed, animal protein is already practically at this level.

Nevertheless, two factors may work in the opposite direction. Firstly, statistics of food production tend to be on the low side in countries where the greater part of the food produced does not enter commercial channels. Present consumption levels may therefore be

somewhat underestimated. This may be offset in part by unrecorded losses from spoilage and other causes.

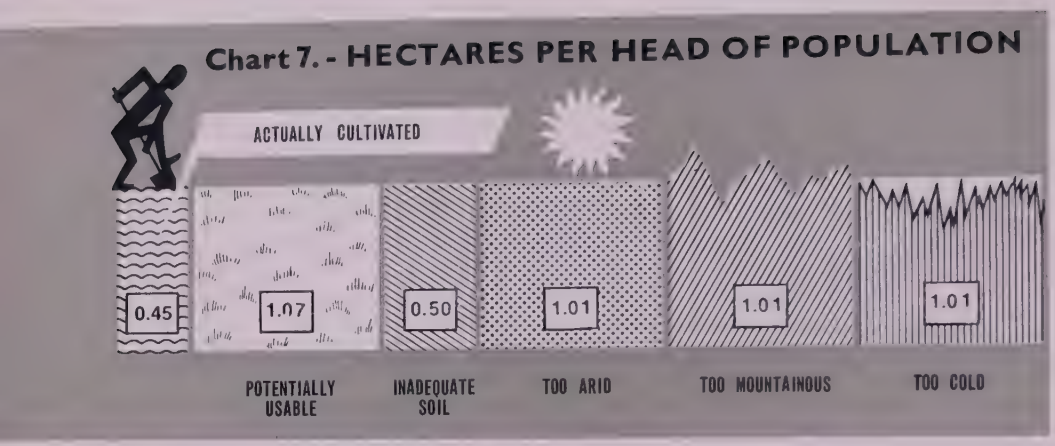
Secondly, the regional price weights used in calculating the indices of production would seem likely to contain an inherent bias for the purpose for which they have been used. For instance, meat or milk is usually expensive in regions where they are scarce and little used. Their price relative to the price of grains would therefore be likely to decline under conditions of greater diversification of agriculture and of diets. Since it is in such products that the greatest percentage increases in consumption would occur, the bias in the price weights could lead to some overestimate in the indices.

On balance, however, it seems that estimates which call for only a 5 percent increase in the value of the diet in Latin America, increases of 17 percent in the Near East, 28 percent in Africa and 67 percent in the Far East, are best taken tentatively as representing the lower limit of requirements.

2. POSSIBILITIES OF EXTENDING AREAS UNDER CULTIVATION

There is probably no aspect of the subject in which it is necessary to choose one's language with greater care than that of evaluating the possibilities for bringing new land into use. Many of the apparent differences in the conclusions drawn by various authors are traceable to the fact that they are really talking about different things. For instance, there is no necessary conflict between the statement that "large areas capable of easy development no longer exist in the world today," and that "the potential unused land resources of the world are very great." The key word in the first quotation is "easy" and in the second "potential." Real divergences of view on this subject, divergences often of vast dimensions, do however exist, as may be seen by comparing Pearson and Harper's "There is little immediate or even *long-time* prospect of materially expanding food production by bringing in new acreage," with De Castro's "Great tracts of unused land lie waiting to be tilled."

Approximately 10 percent, probably a little more, of the land surface of our globe is under cultivation, amounting to about 1,400 million hectares, or a little under half a hectare per person, though no particular significance should be given to any such ratio, since everything depends on how each hectare is used. The area under crops in any one year is much less than the area under cultivation. There are no statistics which can tell us to what extent the area either under cultivation or under crops has increased in the world as a whole during the last century or half-century. However, approximate figures for cereals, which occupy the greater part of the total, indicate that crop area continues to expand, being at present some 30 percent higher than before the first world war and 18 percent higher than before the second world war. Expansion of the cultivated area in the U.S.S.R. is remarkable. Between 1953 and 1957, about 36 million hectares of



new land (virgin and abandoned soils) were opened to cultivation, of which nearly 27 million were in Kazakstan and Siberia. [1]

Estimates by reputable geographers, soil scientists and others of the possible extent of the cultivable land, are by no means lacking. Writing in 1930, Fawcett, after a rather summary analysis, concluded that " some 30 percent of the total land area of the world can be regarded as cultivable land capable of producing the ordinary crops of agriculture."[2] This would amount to somewhat over 4,000 million hectares. Stamp, in a similar but rather fuller analysis in 1952, does not venture a final figure, but after deducting that which is too cold, too dry or too mountainous, is left with 40 percent, from which " much more must be eliminated because of the absence or poverty of soil or because of excessive rainfall."[3]

Taking a somewhat different approach, Kellogg states: " It seems reasonable that at least 20 percent of the unused tropical soils in the Americas, Africa and the great islands like New Guinea, Madagascar, and Borneo can be cultivated. This might give us one billion additional potential acres (400 million hectares). " [4] He also considers that the acreage under crop in the podzolic soils to the north of the

[1] FAO. *The state of food and agriculture 1958*, p. 203.

[2] R.G. Fawcett, The habitable globe. *Geographical Journal*, Vol. 76, 1930, p. 509.

[3] L.D. Stamp, *Land for tomorrow*. Bloomington, Indiana University Press, 1952, p. 52.

[4] C.E. Kellogg, *Food, soil and people*. New York, Manhattan Publishing Co. in co-operation with UNESCO, 1950, p. 21.

temperate zone could be increased to 10 percent from the present 1 percent "if transportation and industry could be developed along with agriculture," providing about 120 million hectares of new land. On the other hand, Pearson and Harper, in an exercise similar to that of Fawcett and Stamp but in more detail, came to the conclusion that only a little over 1,000 million hectares or 7 percent of the world's land is "adapted to food production," i.e., less than is now under cultivation.[5]

A common feature of all these estimates is that they are based on global judgments rather than derived from a study of individual regions. It is not proposed to attempt in this study another over-all estimate of potential arable land, since any figure with a reasonable claim to superiority over the best existing estimates would need to be built up from a careful survey of a very large number of separate areas. The first step toward such an investigation would be to identify these areas as systematically as possible without trying to delimit them precisely. A preliminary essay toward identification will be attempted, but it must be emphasized that it partakes more of the nature of a series of examples rather than a comprehensive list. At the same time, some attention will be given, wherever possible, to the principal problems, so far as they are now known, of bringing these lands into use.

Because climate is the primary control as regards the extent and character of agricultural possibilities, and also determines for the most part the kind of problems encountered, the areas offering the principal opportunities for expansion will be grouped according to broad climatic types. No one system of climatic classification is followed rigidly but in the main the treatment adheres to Koeppen's system.

Equatorial lands (Koeppen Af type)

The continuously hot, continuously wet, belt lying athwart the equator presents the most conspicuous gap in a world map of sedentary agriculture. As Stamp says, "Over huge areas the equatorial lands are scarcely to be described as underdeveloped. They are literally

[5] F.A. Pearson and F.A. Harper, *The world's hunger*. Ithaca, N.Y., Cornell University Press, 1945, p. 48.

FIGURE 1. — Tropical rain forest, Malaya.

FIGURE 2. – Equatorial tropical grassland, Congo.

undeveloped and largely uninhabited."[6] Despite minor differences in identification in different systems of climatic classification, one can distinguish with reasonable assurance the following principal occurrences over land surfaces :

1. An extensive area in Africa from somewhere north of the mouth of the Congo to the mouth of the Niger and stretching inland to cover the central part of the Congo basin until it is terminated by the East African plateau.

2. Most of the Malay peninsula and Indonesian archipelago, including Malaya, Sumatra, Kalimantan, Mindanao, Sulawesi, the western two thirds of Java and the whole of New Guinea, except the south-central projection approaching Australia.

[6] L.D. Stamp, *Op. cit.*, p. 60.

3. The upper and central Amazon basin and the Atlantic lowlands of Colombia.

Similar in climate, though not on the equator, are three east coast fringes. Two of these are in the Southern Hemisphere, namely, the east coast of Madagascar and the coast of Brazil in the same latitudes as Madagascar; and in the Northern Hemisphere there is the Pacific coast of Central America from Guatemala to Panama, the east coast fringe being continuous in this case with the equatorial climate of the Atlantic coast of Colombia. These continuously wet coasts differ from the belt along the equator only in having slight seasonal variations in temperature. The typical vegetation of these areas is the tropical rain forest, a climax vegetation characterizing a climatic type with heavy rainfall more or less evenly spread throughout the year, and high temperatures.

A glance at the map shows how limited are the areas which have been developed: Java, parts of Malaya, pockets on Sumatra, the banana plantations of Central America, scattered plantations of rubber, oil palm, coffee and bananas in the Congo and Cameroon, and on the east coast of Madagascar. (See map at end of volume.)

Aided by a young volcanic soil and a topography and river system permitting irrigation by people lacking modern engineering devices, the early settlers have in the course of centuries turned Java into a garden. The great islands of Sumatra, Borneo and Celebes remain predominantly jungle, and even Malaya is still 80 percent jungle, while much of the best rice land of level, clay soils is occupied by rubber, which is capable of growing almost anywhere in the country. Differences in the fertility of the soils, many of which on Sumatra are volcanic in origin and, although older, apparently not too greatly inferior to those of Java, appear inadequate to explain the extreme differences in population density in the various parts of this region. Possibly more important is the fact that the river systems in many of the other islands and particularly in Sumatra and Borneo flood easily over vast plains and require to be controlled at their headwaters before they can be turned to service. In Malaya, where the clays hold the water in colloidal form, absence of a water table has practically confined settlement to the river banks and sea coasts.[7]

[7] William O. Douglas, *North from Malaya*. New York, Doubleday, 1953, p. 89.

The situation in Indonesia illustrates very well the fact that frequently it has been the establishment and survival of the nucleus settlement that was the important thing. Once in existence this nucleus has continued to grow, leading to ever more intensive development of the natural resources until they could support a dense population, while other areas where the nucleus did not survive have often remained for centuries practically uninhabited by sedentary farmers. Survival in any particular environment depends largely on the technical capacities available at the time. Today, capacities in the fields of irrigation engineering, drainage, sanitation, and agricultural practices, for instance, are so changed that there often remains little correlation between historically determined population densities and land use potentials in the light of present-day knowledge. Now that Java has become so densely populated and modern technologies have opened up new possibilities, another period of establishment of settlement nuclei has begun in recent decades. Indonesia has taken the first steps toward vast projects designed to develop the "outer islands," comprising an extensive series of soil surveys and a combined program of drainage and irrigation on Sumatra and Kalimantan. It is hoped ultimately to bring approximately 1.7 million hectares under irrigated farming. In addition, an extensive program for the development of unirrigated land and mechanized agriculture has been initiated.

It is probable that development of the two areas where the equatorial climate spreads over a continental land mass, namely, the Congo and Amazon basins, will prove considerably more difficult than the islands of the East Indies. In the first instance, attention is likely to be centered on the alluvial soils (provided they can be protected from flooding), both because of their greater fertility and because they are more accessible by river transport. One of the distinguishing features of the Congo basin, for instance, is the widespread alluvium bordering the lower courses of a large number of its tributaries, and one student of African geography claims that in this respect "the potential agricultural resources awaiting development are on an immense scale."[8]

However, relatively little is yet known about these alluvial soils, which are also said to consist largely of highly leached sandy soils in many areas. Returning to the question of the Congo basin as a

[8] W. Fitzgerald, *Africa*. London, Methuen, 1961.

whole, an over-all perspective can best be obtained from the observation that this vast territory has a population of only 12 million inhabitants (within the political limits of the former Belgian Congo), although it covers a larger area than western Europe.

While speaking of the heavy rainfall areas of Africa, one should also not overlook the almost untouched tropical rain forest lands of Sierra Leone, Liberia and the Ivory Coast, although their agricultural possibilities and the potential land use pattern differ considerably from the equatorial climate proper, since they are marked by alternating wet and dry seasons. Even if one considers only the systematic exploitation of the food resources existing within the forest, their contribution to the world's food supply could be greatly increased. For instance, Fitzgerald considers that exports of palm oil from the Ivory Coast, without development of plantations, could easily amount to 200,000 tons as against the present 8,000 tons. Much greater are the possibilities from a plantation system, under which the oil palm would be cultivated instead of being merely exploited and under which improved varieties, some of which already exist, could be introduced. It has been estimated that plantations occupying 1 percent of Sierra Leone could produce as much oil as the existing commercial output (Fitzgerald). Although large areas of these territories are used for subsistence agriculture under the extensive method known as shifting cultivation, plantation agriculture yielding valuable export commodities might be developed if these areas were penetrated by roads or railways. The same is true of the greater part of the Congo and Amazon regions, although river transport plays a vital role in the plantation agriculture of the Congo basin.

In Latin America, the agricultural possibilities of the Amazon basin remain little known, though the difficulties are obvious to all. But one part of this basin deserves special mention. The eastern slopes of the Andes, providing the hinterland for Colombia, Ecuador, Peru and Bolivia, although draining into the Amazon basin, require to be sharply differentiated from the Amazonian lowlands. Because of their elevation they afford pleasant temperatures, especially at the upper levels, and have been described as enjoying "perpetual spring." This vast, temperate, well-watered area with its lush vegetation, stretching from Colombia through northern Bolivia, is one of the untouched portions of the globe. Cut off from the west by the continuous high

mountain chain of the Andes and from the east by 3,200 kilometers of equatorial lowlands, the eastern extensions of the Andean countries have remained outside their effective national territory. However, it may well be that had these lands been part of the territory of a state with the expansive power, capital and technical skills of, shall we say, the United States, they would today be closely tied to the commerce of the world. To the usual problems of dealing with soils receiving a heavy rainfall, one must add in this case a high degree of inaccessibility. Furthermore, the land is for the most part too rugged for annual crops. It will undoubtedly require a heavy use of fertilizers to offset leaching, fertilizers which under present transport facilities could probably not be brought in economically. The key to the development of the eastern slopes of the Andes is transportation, both to bring in the fertilizers and other requisites needed, and to provide an outlet for the products. Given adequate transportation and use of fertilizers, the area would be suitable to an economy based on tree crops and grass leys for livestock farming, on condition that this system of farming is successful in ensuring the conservation of the soil presently ensured by the forest cover.

The continuous heavy rainfall and unceasing high temperatures are responsible both for the agricultural difficulties and the agricultural possibilities of the equatorial lands. The natural vegetation is that most luxuriant of all types, the tropical rain forest. Yet it cannot be without cause that, with a few notable exceptions, these areas have never known anything but the hoe or the stick of the shifting cultivator, the most extensive and primitive of all forms of agriculture. Except where soils are geologically young, the excessive rainfall has long washed practically all the plant nutrients not tied up in living vegetation from the topsoil, carrying them out through the drainage water or away in the surface run-off. Although the heavy forests provide large quantities of humus on the surface, the humus content of the soil itself is not nearly as rich as that built up over long periods by decaying grassroots on, e.g., prairie soils. When the forest cover is removed, the soils are subject to extremely rapid decomposition of the organic matter that exists, because of the high temperatures, and to extremely rapid leaching of the mineral matter because of the heavy rainfall. These processes are accelerated by plowing, especially if the soil is left without a crop cover for even a limited time.

Disease has also severely limited man's occupation of the rain forest. In Africa, for instance, malaria is still endemic, even though now partially controlled. Yellow fever, formerly a killing disease, has only been controlled for about 25 years. Yaws, onchocerciasis (river blindness), leprosy, human trypanosomiasis and parasites are all endemic, though in many cases their incidence has been much reduced. The tsetse fly makes it almost impossible to keep cattle, and milk is thus an expensive luxury.

According to one writer, in Africa "man occupied the open savanna country first because he was a hunter; later he penetrated the dry deciduous forest, which he destroyed to establish cultivated fields, and much later still he was pushed on to the edge of the tropical rain forest where he lived precariously on roots, bananas and fish until the arrival of the Europeans."[9] It is the more primitive pygmy, pushed much earlier into the retreat of the tropical rain forest, who learned to become at home in it as a hunter and food gatherer but not as a cultivator.

It is readily understandable that in the past mankind has not been able, except in areas with special advantages, to establish a stable agriculture in "these regions of lasting difficulty."[10] It is, however, hardly conceivable that armed with the resources of modern science and wealth for research and investment man will not ultimately make himself master of these lands, turning to good use their abundance of moisture and heat, capable of bringing to maturity two and even three crops a year. But before this is possible, there will have to be a great deal of research and very large investments.

Some of this research has already been carried out. For instance, INEAC (Institut national pour l'étude agronomique du Congo belge [the former Belgian Congo]), was engaged in such a research program from 1933 to 1960 with 26 experimental stations in the area. One of the results of this work has been to emphasize the importance of allowing many soils to return to forest periodically, of conserving and building up the content of organic matter, which is of even greater importance in the tropics; of shade, since the strong sunlight destroys organic matter, leading to a rapid loss of nitrogen; of mixed

[9] N. Heseltine, *Remaking Africa*, p. 52.
[10] H. J. Fleure, quoted by L.D. Stamp, *Op. cit.*, p. 63.

cultures and continual cover, and of avoiding excessive cultivation. This technique was followed in the corridor system, in which an area was divided into a number of corridors, say, 1 or 2 kilometers long and 300 meters wide. A new corridor was brought into crop each year and, after perhaps six years under various crops, each corridor was allowed to return to forest for 10 to 12 years.[11] This, of course, is an adaptation or rationalization of the traditional system of shifting cultivation as a means of restoring soil fertility. In the absence of further improvements in land use, including particularly the use of fertilizers, there remain many unknown factors in this empirical practice of restoring fertility. What is important is that using natural regrowth as the main means of fertility maintenance, the period of bush fallow should not fall below a minimum which may vary from 10 to 20 years.[12]

Although it appears that leguminous plants are not as efficient for azote fixation under tropical conditions as in temperate countries, it is not impossible that further investigations will show the possibility of substituting for the long forest fallow agricultural rotations ensuring the restoration and maintenance of soil fertility in the same conditions as the cover of forest trees. Such plants would have their maximum usefulness after suitable methods had been devised to incorporate them into the soil at the end of the forest rotation, without the loss of organic matter and nitrogen, and without the liberation of the easily lost soluble mineral nutrients that is so characteristic of the present systems of shifting cultivation through the burning of the forest cover.

In some circumstances, it may be possible to maintain soil fertility with field crops without including forest or a forest substitute in the rotation by reproducing the ecoclimate of the forest by tree crops, to keep down soil temperatures and control run-off in some measure. It has also been repeatedly shown that tree crops, such as rubber, cocoa, oil palm, citrus and other similar crops, can be grown in more or less permanent plantings along with leguminous or other ground cover. It is probable that for many crops a fairly heavy use of mineral fertilizers, as well as careful attention to organic matter, will be necessary

[11] See FAO Agricultural Studies No. 4, *Soil conservation: An international study*, 1952.

[12] See H. Lauderlout, *Dynamics of tropical soils in relation to their fallowing techniques*. A study prepared for the Land and Water Development Division, FAO, 1962.

for high yields, but the balance of nutrients needed is different from that in temperate regions and must be ascertained through research.

In any case, the fundamental problem of establishing agriculture on a permanent and self-sustaining basis in the equatorial lands is that of finding techniques whereby the cultivator can support himself in the same place, not only maintaining but eventually learning to increase the fertility of the soil. In Africa, where the problem arises already in an acute form, it is impossible for the cultivator with existing techniques to remain on one piece of land and maintain its fertility. An adequate program of research on soil types, on ecology and on management of soil and vegetation, will clearly need to be organized on an international basis.

Hardly less important is the control of plant and animal pests and diseases, where an internationally co-ordinated program is again essential.

It is still much too early to predict future potentialities in the equatorial lands, but we can feel confident that cropping patterns and management methods suitable to the environment will be worked out and will eventually permit the development of an efficient and productive agriculture over large parts of what is now tropical forest in Africa, in southeast Asia and, probably somewhat later, in Latin America. At the same time, large areas presently bearing valueless scrub and secondary regrowth instead of the magnificent trees of the destroyed virgin forests, might return to the forest and yield raw material for the development of big and small rural industries. It is even possible to combine on the same area agriculture and forestry by following the pattern of the so-called taungya method, which has long been used in Asia and was recently introduced in Africa and Latin America. We can agree with Kellogg that "on the whole the long-time potentialities in the tropics can be regarded as enormous, with the application of a symmetrical agricultural science."[13] An important point here is that once the problems of maintaining soil fertility and controlling disease have been solved, rainfall and temperature will permit of cropping in all seasons, thus multiplying the physical extent of the area brought under agriculture two or three times in terms of crop area.

If this analysis is basically correct, an agricultural revolution comparable to the opening up of the grass and forest lands in the tem-

[13] C.E. Kellogg, *Soils that support us*. New York, Macmillan, 1941.

perate areas of North and South America and Australia lies somewhere ahead. The difference, and it is a great one, is that whereas the former awaited only the individual pioneer provided with transportation for his products and using techniques he had brought with him from not too dissimilar lands in Europe, the vast equatorial expanses will require the co-ordinated efforts of governments, using the full resources of science and capital. Furthermore, the mistakes conducive to soil erosion and loss of fertility which were made in the clearing of the temperate forests should be carefully avoided.

The savannas (Koeppen Aw type) of Africa, America and Australia

North and south of the equatorial belt, rainfall is not only much lower but is confined to one period of the year. Here, also, broad regions are so little utilized over three continents as to justify some treatment of the type as a whole. While the tropical savannas do not present the same initial difficulties to the penetration of man as the tropical forests, it is likely that they will be less rewarding in the long run, characterized as most of them are by less reliable precipitation and a drought season (of increasing length as one moves toward their outer margin), when agriculture is impossible except under irrigation.

The little-used, in some cases unused, lands falling into this type include a broad belt in Africa between the Sahara and the equatorial rain forest stretching from Senegal to Somalia (the prototype of the Sudan climate), the Orinoco basin (llanos) in the same latitude in South America, much of Africa south of the equator, a vast area in Brazil, the adjoining lowlands of Bolivia and northern Paraguay and the northernmost and northeastern parts of Australia. At present, these parts of the world are used principally for extensive cattle ranching, with a very low output per hectare. This is in strong contrast to the situation in southeast Asia, in many parts of which the climate is basically similar, in respect of the alternation of the wet (or monsoon) and dry seasons (see subsection on the settled monsoon and savanna lands of Asia, p. 59).

To what extent there exist climatic differences which would be significant for land use between these savannas and the long trans-

FIGURE 3. – Medium savanna, medium rainfall, Tanganyika.

FIGURE 4. - Dry savanna, low rainfall, Tanganyika.

FIGURE 5. – Milking time in Tanganyika. Such cows yield 1 to 3 liters per day, approximately 455 to 685 liters per lactation.

great stock industries of the Argentine pampas and the Australian Downs."

This will, however, require a multitude of changes, which would ultimately bring the present almost closed societies of cattle people into the commercial economy. The tens of millions of cattle, sheep and goats which are spread over a quarter of the land surface of Africa are certainly the only way of converting the unpromising vegetation of this area with a dry season of nine to ten months into products usable by man. But the yield is very small. " For the cattle peoples to become productive, in the sense of having a regular surplus of high quality of which they can dispose, their equilibrium with their surroundings must give place to a scientific utilization. At present, they use water and grazing up to the limit imposed by nature; to become productive they must gain control of these natural resources so as to expand and renew them. The unpredictables, such as rainfall and animal disease, can be very largely controlled by developing groundwater supplies and surface-water storage, and by scientific disease control. But digging wells and tanks will not by itself produce the transformation. Increase of water supplies alone will mean increase in the total numbers of livestock, but unless these increased numbers have more and better fodder, and unless their owners have improved abattoirs, meat marketing and transport, the bigger herds will only run down the range, and lead to large flocks of half-starved animals." [15]

It is in the provision of fodder that the link may be forged between the large transhumant and nomadic herds and the cultivators, who are found everywhere on the fringe where rainfall becomes sufficient for agriculture. The transformation of the cultivation from a system of migratory subsistence agriculture to a diversified sedentary agriculture is necessary to provide the link with the cattle owners of the drier north. An efficient use of the two environments would involve movement south of beasts ready for " harvesting, " for fattening as the pastures grow drier. The next stage could involve the emergence of true mixed farming where the two regions meet, to the mutual benefit of the livestock and the soil. Along with better feeding it will, however, be essential to adopt selective breeding for quality.

[15] N. Heseltine, *Op. cit.*, p. 37.

In West Africa, great importance must be placed on the opportunities for irrigation offered by the Niger and to a lesser extent by the Senegal. The former, rising in territory of heavy rainfall, flows northeast to pass through semidesert country before turning south again. Near its northern loop, south and southwest of Timbuktu, it floods annually an enormous area, the possibilities of which were investigated by the Belime Commission in 1929. The Commission recommended as the first stage the irrigation of about 700,000 hectares. According to Fitzgerald's estimates, continuation of the Bamako-Ségou canal would bring " at least 5 million acres (2 million hectares) of land within its range." Two other projected canals would make possible the cultivation of something in excess of 400,000 hectares. As stated by Fitzgerald, " The flat irrigable area of the Middle Niger is very much greater than the Nile lands of Egypt."

So far, these projects have resulted only in the completion of the Sansanding dam in 1947, with the aid of which about 50,000 hectares have been fully developed by the Office du Niger, although 156,000 hectares are covered by irrigation channels. This scheme was originally intended to produce cotton as in the Gezira, on 400,000 hectares, but it has fallen short of this, partly owing to its unfavorable pest and disease position, to the variable soil types, and failure to persuade sufficient Mossi, of whom 1 million were expected, to emigrate permanently from the Upper Volta. However, this " fossil delta " has an enormous potential if these problems can be overcome.

The belt of heavy summer rainfall with winter drought extends eastward into Ethiopia and the plateau of East Africa, though its effects on vegetation are modified here by altitude. A few examples, drawn from areas which have been little utilized, because of certain initial handicaps which modern engineering and agricultural science can overcome, must suffice. One of these is the vast shallow depression occupied by Lake Kioga, through which the Nile passes on its way from Lake Victoria to Lake Albert. " Sooner or later the vast marsh region of Lake Kioga will be reclaimed for cultivation. Even under present conditions there are very favourable prospects for wetland rice. "[16] Another is the lower part of the Rufiji basin in Tanganyika, where there exists an irrigable area of some 120,000 hectares, of which

[16] W. Fitzgerald, *Op. cit.*

about one third is now being farmed through taking advantage of natural inundation. The irrigation project proposed here would lead to higher average yields on the existing area, as well as greatly extending the area which consists of highly fertile alluvium. A more extensive area but presenting also problems of drainage and settlement, as well as irrigation, is to be found higher up the Rufiji basin in the Kilombero valley.

In Madagascar, where basically similar climatic conditions exist in the western two thirds of the island, the population has historically clung to the central highlands for reasons probably similar to those which have forced peoples with low technical skills to shun easily flooded and unhealthy lowlands in many other parts of the tropics. Although movement into the agriculturally rich western lowlands has begun, the extensive areas of alluvium in the lower basins of the westward-flowing rivers, with their possibilities for cotton, sugar cane and rice, remain largely undeveloped, although in recent years considerable increases in areas under cotton have been undertaken and a sugar cane project is in operation.

The Okovango delta in north Bechuanaland has been reported to possess an agricultural potential of some millions of hectares. It is at present almost uninhabited.[17]

The agricultural and pastoral potentialities of Ethiopia, one of the most favorably endowed parts of Africa, have been repeatedly testified to by technical assistance experts. The United States technical mission during the second world war came to the conclusion that "Judging by the land in the plateau areas which is now in cultivation, amounting to over one fourth of the total area, there is fully as much more equally suitable for cultivation so far as topography is concerned," while recognizing that an extension of cultivation requires changes in grazing and shifting cultivation practices.[18] Nicholson found that "Ethiopia possesses at least seven distinct areas totalling about 7 million hectares suitable for cotton growing," of which "probably 800,000 to 1,200,000 hectares could be used for this purpose without seriously interfering with the production of sorghum and other food

[17] See J.H. Wellington, *Southern Africa*, Cambridge, Cambridge University Press, 1955, for reports of a preliminary survey by A. Dutoits in 1925/26.

[18] Unpublished manuscript in possession of a member of the mission.

FIGURE 6. - Ethiopia is potentially an important meat-exporting country. Photo shows a herd of cattle watering at a small river in the west of Shoa province.

crops."[19] The present area under cotton is about 10,000 hectares. In recent years, particular attention has been given to the Awash basin, the resources of which are now under survey. It has already proved very suitable for sugar cane.

Given effective control of rinderpest and other diseases, good pasture management and watershed management, Ethiopia, with 15 to 20 million head of cattle, could become one of the important meat-exporting countries of the world. The United States wartime mission calculated that with effective use of present numbers, over 1.5 million cattle should be available for slaughter each year and that, after allowing for introduction of meat into the regular diet, of the total, perhaps 300,000 could be slaughtered for export, a figure which might be increased considerably if avoidable losses through disease were stopped.

Reference has already been made in appropriate places to the potentialities of some of the river basins of Africa, such as the Niger and Rufiji. But the potentialities of the river basins, most of which pass through or lie principally in the savanna belt, are little utilized as a general rule, because the inhabitants have lacked the techniques for occupation of the river valleys.[20] Forced out by the gradual desiccation of the Sahara, neolithic man conquered the swamps of the Lower Nile and in the course of meeting this challenge created one of the first civilizations. This success was, however, achieved under unusually favorable conditions, where the bed of the river is deeply entrenched. There existed therefore both the challenge and the favorable physical conditions. There was perhaps also the opportunity to learn from, or share experience with, other communities, most notably that of the Tigris-Euphrates basin, in the Near East.

In the savannas, the possibility of occupation of the plateaus or of the catchments took the sting out of the challenge, while extensive and often unpredictable flooding and disease kept man away from what are potentially the most productive lands under modern techniques for resource control and resource use. One writer claims that "no *African* culture had developed any kind of irrigation at the time of the

[19] G.E. Nicholson, *Interim report on cotton production in Ethiopia*, Addis Ababa. FAO, Rome, 1953.

[20] N. Heseltine, *Op. cit.*

first colonial penetration, and irrigation, where it has been introduced, is either practised by Europeans, as in Rhodesia and the Portuguese territories, or by Africans on settlement schemes, under very close official control and supervision. On all new pilot projects for irrigation, such as at Kilombero on the Rufiji, there is the problem of teaching the African cultivator to use water. Irrigation must be a daily, orderly routine practice. It cannot be carried out in the sporadic way of the semi-shifting cultivator. It requires a sense of the community and a discipline in the sharing of the water. It also requires economy for efficient use of water, and the maintenance of canals and above all of drainage systems."[21] However, Davidson considers, on the basis of recent archeological findings, that there is ample evidence of highly organized agriculture with irrigation in Africa, especially in East Africa, before the arrival of Europeans.[22]

Thus to this day the extensive area of the Nile known as the Sudd remains a primitive swamp, occupied only by cattle-owning Nilotic tribes. Man has not occupied, except sporadically, the Rufiji basin, which covers one fifth of Tanganyika, because of tsetse, malaria and wild animals and because of his inability to control the floods. In Rhodesia, the plateaus are inhabited rather than the valley of the Zambesi. In Kenya, the highlands have been preferred to the Tana. Much of the Limpopo valley is uninhabited. The basin of the Volta has been shunned mainly because of onchocerciasis or river blindness, as well as the inability of the population to control floods.

Development and settlement of the alluvial lands, following flood control, therefore constitutes a tremendous potentiality in Africa. "The control of water means that rice production immediately becomes not only possible but a most efficient way of using it. Water-control also means that maize can be grown under almost continuous cropping in tropical regions."[23]

Northern and northeastern Australia lie in the monsoon belt, which extends through from southeastern Asia, though the seasons are of course reversed in the Southern Hemisphere. The developmental opportunities appear to lie in two directions: firstly, in taking

[21] N. Heseltine, *Op. cit.*, p. 61.
[22] Basil Davidson, *Old Africa rediscovered.* London, Gollancz, 1959.
[23] N. Heseltine, *Op. cit.*, p. 65.

advantage of the natural flood plains along certain of the rivers; secondly, in rainfed agriculture, aided by supplementary irrigation wherever possible. Near Darwin, along the Ord river (Wyndham) and along the Fitzroy river (Derby), it has been estimated that perhaps 200,000 hectares could be brought under rice cultivation — a figure which may, however, be much too high. Investigations have also shown the feasibility of growing the usual summer crops of the savannas (groundnuts, tobacco, summer cereals) in the broad Arnhem peninsula which receives a rainfall ranging from 750 to 1,500 millimeters, with five to six months of adequate moisture.[24] Similar precipitation evaporation relationships exist on the Cape York peninsula, which is now under investigation regarding its agricultural potentialities. It is worth noting that the moisture conditions in the Darwin area are considerably more favorable than in the well-established agricultural belt in central-northern Burma around Mandalay. Very substantial increases in cultivated area would be possible in the higher rainfall areas of eastern Queensland, where the same kind of crops can be grown under rainfed conditions as has already been mentioned for the Arnhem peninsula.

Perhaps more important than the possibilities for crop production in tropical Australia are those for placing livestock production, and particularly cattle, on a more stable and intensive basis. Throughout the vast expanses of the cattle industry of Queensland and the Northern Territory one can say that, apart from the provision of a limited number of water holes, man has used nature as he found it, with little or no attempt at improvement, except in the areas of higher rainfall in the east. Dr. Griffith Davies, writing only on Queensland, envisages the long-range possibility of tripling the cattle population — an increase exceeding total cattle numbers in the United Kingdom — through pasture improvement, once suitable legumes have been found as a result of the research now being carried out. Ultimately, intensification will also occur in the Northern Territory.

Since 1953, a team of scientific workers in the Division of Tropical Pastures of the CSIRO has carried out a systematic study of plant species designed to use these environments, with principal reference to specific mineral deficiencies and climate. "During the past five

[24] CSIRO, *Soils of the Katherine-Darwin area, Northern Territory*. Melbourne, 1956.

years species of legumes and grasses have been introduced, their nutritional requirements specified, and new varieties made by plant breeding. Pasture yields have been raised from 1,680 to 2,250 kilograms dry matter per hectare per annum to 22,450 kilograms dry matter per hectare per annum in a 1,000-millimeter rainfall area without recourse to irrigation. This demands massive amounts of fertilizer and it yet remains to make this ten-fold increase of yield into an economic agricultural reality. But the potential increase in food supply, meat, dairy products and crops is clearly an enormous one." [25]

This research should in time be of tremendous importance over much of southeast Asia, Latin America and Africa, though the basic method will naturally have to be supplemented by local applied research, particularly with reference to mineral deficiencies.

Much less is known of the specific agricultural possibilities and difficulties of the vast expanses of savanna lying north and south of the Amazon basin. Except for extensive cattle ranching, on a basis similar to northern Australia, these remain unused. The llanos of the Orinoco basin have for four centuries disappointed the original expectations of the Spanish settlers, who let loose their cattle in these apparently rich grasslands. Today we understand better the vast differences between the natural pastures of western Europe and the tropical savannas with their alternations of flood and drought, overrapid growth and quick deterioration of the unmanaged pastures. But we also know that the failures of four centuries are the failures of man to control the floods, provide drainage, provide water and shade, correct soil mineral deficiencies and improve and manage the pastures. An example of what can be done has recently been furnished by a ranch in the Lake Maracaibo region 10° north of the equator where, without irrigation but on highly improved and well-managed pastures, 1,800 cattle are carried on 2,000 hectares.[26]

Further light is cast on the possibilities of these areas by the work of the Ebini Livestock Station located in the savannas of inland British Guiana. (Note, however, some differences in the rainfall regime here from the normal Aw type.) Prior to the establishment of

[25] Private communication from Dr. J. Griffith Davies, Chief, CSIRO Division of Tropical Pastures.

[26] See *Report of the Proceedings of the Eighth Pacific Science Congress.* Quezon City, Philippines, 1955.

the station, all attempts to raise cattle on the savannas had ended in failure, since the animals failed to breed and did poorly. This has been shown to be due to mineral deficencies in the diet, and cattle have responded well to the feeding of a mixture containing phosphorus, calcium and minor elements. Controlled burning and rotational grazing have resulted in marked improvements in the composition of the pastures, while small amendments of minerals to the soil have led to legumes becoming an important part of the sward. It is also considered that cowpeas and several grain crops, including sorghums, maize, and in the low-lying areas rice, offer possibilities.[27] The discovery of the importance of paying attention to trace elements fits in well with Australian work in this field.

The tropical grasslands of Brazil, covering an enormous area to the south of the Amazon rain forest, are at present used in the hinterland almost exclusively for extensive cattle ranching on a basis not too dissimilar to that of northern Australia. Cattle are mostly of a poor type, descendants of the unimproved breeds brought from the Iberian peninsula by the early settlers, but in some areas, particularly in the central plateau, some improvement has been carried out. Carcass weights in Brazil, including in the calculations the modern European breeds of Rio Grande do Sul, average around 190 kilograms compared with around 240 kilograms in the United States and Australia, where for the most part extensive ranching also prevails. With a rainfall ranging from 1,000 to 2,000 millimeters, and a season of about six months of adequate moisture, it would appear probable that a substantial proportion of this hinterland is destined ultimately to be utilized much more intensively with cereals and other crops, improved pastures and better breeds of cattle. Development is likely to encompass first the Planalto Goiano or central plateau, which, in addition to relatively favorable natural conditions, has the advantage of being closest to the settled areas of the southeast. In this area are concentrated many of the new colonization schemes of the Government of Brazil.[28]

[27] P.G. Hogg, *The research program for livestock improvement and grassland management at the Ebini Livestock Station.* Rome, 1953. FAO ETAP Report No. 184.

[28] See Goias, *Uma nova frontiera humana*, by the Council of Immigration and Colonization, Brazil.

Resource conservation in Africa[29]

It would be misleading to leave this section on the potentialities of the savannas without drawing attention to one important difference between Africa on the one hand and South America and Australia on the other. The latter are, or until recently were, virgin lands, while the savannas of Africa have been under occupation and often the center of a struggle for existence for centuries. In the course of this struggle, grave damage has been done to vegetation and soil in many parts and, with the growing pressure of population, the rate of destruction is increasing.

The great weapon of man in his advance across the African savannas has been fire; and fire has been the great enemy of the land. Over extensive areas, the dry deciduous forest that lay between the Sahel (or dry savanna) and the tropical rain forest has been destroyed by the combined action of shifting cultivators looking for new lands and uncontrolled fires set by pastoral tribes and hunters. Unfortunately, the damage once done is much less easily reparable than in the tropical rain forest, where the vegetation is in equilibrium with its environment. In the moister Sudan, the dry forest was a product of earlier and wetter ages and there was not always a stable equilibrium of vegetation adapted to the ecological conditions.

The forests man has destroyed may be difficult to re-establish and the process of degeneration is bound to continue if a re-equilibrium between population pressure and resources is not established through new patterns and techniques of use. The degradation of vegetation profoundly modifies the soil structure and the water regime. More rapid run-off, water erosion in the wet season, and wind erosion in the dry season, more severe leaching in the higher rainfall areas, adverse chemical changes through higher soil temperatures, are all elements in a process which may lead to the formation of laterite or bauxite, according to the type of soil. Beyond a certain point, such profound chemical changes may prove irreversible.

This analysis is not, of course, intended to refer to the whole of the African savannas. As already indicated, large areas remain

[29] Extensive use has been made in this section of Heseltine's *Remaking Africa*. At the same time, the responsibility for the way in which the material has been used is wholly the author's.

lightly populated, in some places almost untouched, although everywhere shifting cultivation, with fire as its inevitable accompaniment, involves damage in the savannas. It does refer with special force to some of the montane areas, which because of higher rainfall have proved specially attractive both to cultivators and to cattle owners, who between them have competed with ever-growing destructiveness for ever-dwindling soil resources.

Perhaps the most dramatic example of this process is to be found in Madagascar, where the destruction of the forest cover has occurred in historical times and is also the most complete. One forester has described the primary forest " flaming like a torch and disappearing completely in a few minutes."[30] Another forester has written, " During the forty years that we have occupied the Island, we have seen thousands of hectares of this primitive vegetation destroyed and transformed into an arid prairie like that of the hills of Imerina."[31] " Today, flying over Madagascar, one sees mile after mile of bare uninhabited hills whose laterite crust is sometimes bare even of grass. The bare hills are the end-product of man's destructive land-use, which would require tremendous efforts to repair, even if it were technically possible to establish forest on laterite."[32] The Fouta Djallon, a mountain outcrop in West Africa, was occupied in the sixteenth and seventeenth centuries by the Foulah cattle owners who subdued the Djallonké cultivators. " Between them, the Foulah and the Djallonké have disastrously destroyed the montane forest climax of the Fouta, which has been replaced by low-grade secondary bush or bare laterite crusts. This forest, like the Madagascar associations, was out of balance with the present climate, with its dry season of five months, and consequently was easily destroyed by fire."[33]

Likewise the Kikuyu, in their 500 years of occupation, have destroyed much of the montane forest, whose rich soils were gradually occupied by shifting cultivation. In Basutoland, where the competition between people and cattle has been particularly acute, " the end of the road has been reached.... The present system of land-use in the Fouta, Ruanda-Urundi and Basutoland, presents two mutually ex-

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[30] J. Coudreau, *La forêt malgache.*

[31] H. Perrier de la Bâthie, *Biogéographie des plantes de Madagascar*, Paris, 1936.

[32] N. Heseltine, *Op. cit.*, p. 51.

[33] N. Heseltine, *Op. cit.*, p. 54.

clusive ways of life, extensive ranching by the dominant cattle peoples, and the efforts of small-scale cultivators to survive on diminishing soil resources."[34]

In the African savannas, both north and south of the equator, we are faced with a situation in which destruction of resources and underutilization of resources exist side by side. The center of gravity of cultivation and of population must shift from upland and more arid areas toward the vast potentialities of the hitherto unusable river basins. Some of the catchment areas need to be taken out of cultivation of annual crops to become either forest reserves or put under tree or bush crops, such as tea.

In other areas, the first condition for a productive and nondestructive agriculture is, as has already been noted for the tropical rain forest, that the cultivator should have in his possession techniques which will enable him to maintain the fertility of his land. In this respect, a grave danger exists in any policy of social change which would do away with shifting cultivation without recognizing the basic problem of soil fertility. " If the tribal system of landholding is transformed into a system of individual private holdings, without at the same time providing for a wise use of this land, the greater part of the soil, water and vegetation resources of Africa will be exposed to exhaustion and destruction." [35]

The broad principles are clear enough. But their implementation demands much more detailed knowledge of the resources and of techniques for using them. A properly co-ordinated survey and appraisal of the land and water resources of Africa, in order to determine sound patterns of land use and population distribution, is therefore a matter of some urgency. Along with it must go research into the techniques of soil management for specified patterns of use, and research into the locating and breeding of suitable grasses, legumes and other crops for identified types of conditions.

Resource development and resource conservation are obverse and reverse sides of the coin. It is a situation in which it is difficult to stand still. It is necessary to go forward to avoid going backward. If the forward course is followed, there remain immense potentialities in the much abused but still underused savannas of Africa.

[34] N. Heseltine, *Op. cit.*, p. 54-55.
[35] N. Heseltine, *Op. cit.*, p. 66.

The settled monsoon and savanna lands of Asia (Koeppen Am and Aw type)

Climatically similar to the little-used savannas of Africa, South America and Australia is the long-settled region stretching from western India through Burma, Thailand and Indo-China to the northern Philippines. Lying between 10° north and the Tropic of Cancer, it is essentially tropical with a growing season throughout the year; and because of the alternate heating and cooling of the great land mass of Asia, it is dominated by in-blowing winds in winter, so that an extremely wet season is followed by a long period of drought when agriculture is impossible without irrigation. The basic climatic similarities tend to be concealed by the fact that this is an area of old civilizations, dense population and an intensive agriculture which has transformed the face of nature.

It would, however, be unwise to push the climatic comparison too far without point by point comparisons on the amount of precipitation and the length of the dry season. Whereas the savannas of Africa and Australia, but *not* those of the Americas, are transitional from the equatorial to desert climates, those of southern Asia lie between hot wet and a cool wet climate, and the areas where the amount of rainfall is critical are fairly limited.

Secondly, considerable parts of southern Asia where the moisture-laden winds encounter mountains receive so much rain in the wet season that the natural vegetation is the tropical rain forest. It is on these lands that it has been possible to develop the really intensive wet rice culture which supports the densest population in this region — the Malabar coast of India, the Ganges-Brahmaputra delta, southern Burma, the central plain of Thailand, the east coast of Viet-Nam, and Luzon.

Despite the intensive development of the tropical monsoon belt of southern Asia, including widespread use of natural inundation and a considerable amount of controlled irrigation, the opportunities for increasing production through better conservation and use of water are enormous. The areas planted during the wet season and the yields per unit area are subject to considerable fluctuations, while most of the land has to be left idle half the year where there is no irrigation, although temperature conditions are favorable to growth throughout the year. At the same time, this is a region characterized by an abun-

FIGURE 7. – Settled monsoon land, Kandy, Ceylon. Rice paddies and coconut areas cleared by burning from the surrounding jungle.

dance of water resources, both because of the torrential monsoon rains and because a large number of rivers descend across southern and southeast Asia from the snow-covered mountain ranges of central Asia.

The extent of the unused water resources of this part of the world is vividly illustrated in a study conducted in 1950 by the Flood Control Bureau of the United Nations Economic Commission for Asia and the Far East, which estimated the proportion of the mean annual run-off of rivers being utilized at that date as 6.6 percent in Ceylon, 5.4 percent in India, 5.2 percent in Thailand and 0.8 percent in Burma. After allowing for run-off which could not be made available for irrigation, it was estimated that sufficient water exists, if the land were available and commandable, to irrigate 260 million hectares in India, 47 million in Burma, 7 million in Thailand and 2 million in Ceylon. In some countries the water available may be in excess of the land area capable of benefiting from it.

Since then, some countries have made very substantial progress in irrigation and also further progress in measuring their water resources. In India, more recent studies have concluded that of the total river resources of the country, estimated at 1,356 million acre feet,[36] physiographic conditions will permit of the utilization of only 450 million acre feet. The 76 million acre feet utilized in 1951 therefore constituted 17 percent of the *usable* flow. By the end of the second five-year plan, about 27 percent of the usable supply was being tapped. This proportion is expected to increase to 36 percent (11.8 percent of the total annual flow) by the end of the third five-year plan. [37]

Nevertheless, the greater part of the water resources are not used in the higher rainfall areas, which typically obtain 1,000 to 2,000 millimeters a year, almost all of which, however, fall from June to October.

The possibilities that could be opened up in monsoon Asia by properly conceived control and use of water are well illustrated by

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[36] An acre foot of water means the quantity of water required to cover 1 acre to the depth of 1 foot. The same quantity of water would cover 1 hectare to a depth of a little over 12 centimeters.

[37] Letter to J.V.A. Nehemiah (FAO) from Dr. R.S. Sharma, Deputy Economic and Statistical Adviser, Ministry of Food and Agriculture (Department of Agriculture), India.

a case study carried out by FAO of the Lower Ganges-Brahmaputra basin.[38]

The study in question covers the Indian states of Bengal, Bihar and Assam and includes the whole of East Pakistan, an area occupied in 1957 by 130 million people living on 28 million hectares of cultivated land. Both the present situation and the conclusions regarding potentialities may at first seem surprising to those not acquainted with the characteristics and history of agriculture in this region.

Although it is a region with an old civilization, densely settled, and with heavy pressure of population on land combined with extreme poverty, the basic resources of land and water are grossly underutilized. For the most part, agricultural operations are confined to the few months of the year when the monsoon rains provide adequate moisture, and there is a general lack of useful occupation for up to eight months of the year, while the vast bodies of water carried by the Ganges, the Brahmaputra and the Megna (about 1,000 million acre feet a year) roll almost unhindered into the Bay of Bengal.

Adequate explanation of this situation can be found in terms of historical development but adequate justification does not exist in terms of present-day techniques. Over the centuries, agricultural practices have adjusted themselves to the rhythm of the monsoon, which with 1,000 to 2,000 millimeters has made it possible to do without irrigation, even though a late start or failure during the critical flowering period can cause a partial crop failure. Thus both farmers and the government agricultural services have accustomed themselves to a system of predominantly monocultural cropping. Such irrigation schemes as have been developed in the postwar years (with the notable exception of the Ganges-Kobadak project in East Pakistan, undertaken along lines suggested by FAO) have been directed mainly at ensuring against failure of the monsoon rather than for irrigation during the dry season.

Starting from the proposition that with cultivable land scarce and water abundant, resources should be developed toward a pattern which would make maximum use of the land, the study of the Lower Ganges-Brahmaputra basin examined the extent of the possibilities for

[38] *The appraisal of agricultural, fishery and forestry resources in relation to needs in the Lower Ganges-Brahmaputra basin.* Rome, FAO, 1959.

a system of *perennial* irrigation. On the basis of a tentative assessment of water resources in relation to irrigable land, the conclusion was reached that it may be possible to provide an adequate water supply throughout the year to more than half of the cultivable area in the alluvial plain; while irrigation could be furnished to a further area for two of the three seasons during which crops could be grown, given favorable temperatures.

The quantitative estimates are of course subject to adjustment on the basis of more detailed surveys, but the general conclusions regarding the pattern of land and water use remain valid. Subject to detailed surveys, these estimates showed that for the survey area as a whole it should be possible approximately to double the annual harvested area within the present cultivated area — and more than double it on the alluvial plain — in a region which has traditionally been regarded as cultivated to the maximum limits of intensity.

The provision of an assured water supply would also provide favorable conditions for intensive use of fertilizer and higher-yielding varieties. From such evidence as is available, it appears likely that yields under farm conditions for the staple cereals, pulses and oilseeds could probably be approximately tripled under irrigation, provided it were accompanied by good farming practices.

For the survey area as a whole, including upland and other non-irrigable areas, the production potential is estimated at about four times the present level. This would make it possible to support a well-fed livestock industry, as well as meet the needs in plant foods, and so provide a well-balanced diet for up to double the present population.

Similar conclusions regarding the patterns of land and water use which would make much fuller use of the natural resources are generally applicable to the other great river basins of southeast Asia, such as the Irrawaddy, the Salween and the Mekong.

In contrast with the equatorial belt and the undeveloped savannas of other continents, the expansion of production in this region through irrigation raises few basic problems of land use and settlement, but does require a reorientation of thinking regarding the patterns of land and water use in the main river basins, where the greater part of the population lives. The costs of irrigation, drainage and flood control will indeed be high, but the returns in productivity of the land will be several-fold.

Apart from the possibilities afforded by multiple cropping and raising average yields through controlled irrigation, there are substantial areas of potential arable land not now in cultivation in many parts of the region, for example, in Burma, Thailand and Ceylon.

It is often assumed that where farms are small, comprising only a few hectares each, or often much less, there must necessarily be heavy pressure of population on land. In most of Asia, particularly Japan, India, Pakistan, China and Java, this picture is generally correct and farms are often smaller than a family could work. But where modern machinery is lacking and crops require much labor, as does rice, the amount of land that can be handled by a family is quite limited. Hence in Burma and Thailand, where there is still an abundance of land resources, one finds extensive areas of uncultivated potential arable land alongside a heavy density of rural population in relation to cultivated area. Burma, for instance, with a rural population of about 12 million on an arable area of around 9 million hectares, possesses an area officially classified as "cultivable but not cultivated," approximately equal to the area now used for cropping. On the average, this land is undoubtedly of lower productivity than the land now used, and much of it would probably be better under permanent pasture or other perennial rather than annual crops. However, agriculturalists familiar with Burma generally consider that this represents a major potential resource, much of which could be put under crop if required.[39]

Even densely populated Asia presents in the so-called dry zone of Ceylon an excellent example of a land left virtually empty because of the difficulties for settlement created by a longer period of drought and the uncertain incidence of the wet season. With most of the population crowded into the southwest corner of the island, and large imports of basic foods, the Government of Ceylon today looks upon this long-neglected and admittedly difficult zone as one of the country's potential assets. Here, according to official estimates, 540,000 hectares await development, an area approximately equal to that at present under cultivation on the island but used mostly for export crops such

[39] See, for instance, M.S.A. Burr, *An agricultural research program for Burma*, and J.J. Sanders and U Bau Tin, *An economic classification of land in Burma*. Rangoon, Thu Dhama Wadi Press, 1952.

as rubber and tea (*Ten-year plan, 1959-68*, p. 238). The greater part of the area will need to be developed through dry farming techniques allied with careful conservation of the rainfall in hundreds of small earthen "tanks." Irrigation can, however, make an important contribution, especially in the Gal Oya valley, where, of 40,000 hectares suitable for cropping, half can be irrigated. The ten-year development program of the Irrigation Department (1959-68) provides for bringing 160,000 hectares in all under irrigation and at the same time making possible the utilization of over 340,000 hectares of nonpaddy lands above the irrigated areas. FAO is giving technical advice in connection with certain aspects of the Gal Oya project and on research on crops and farming techniques for the dry zone. A thousand years ago and more, one of the great Indian civilizations flourished on the basis of careful water conservation in this region which has for several hundred years past been left to the *chena* (shifting) cultivator, the jungle and malaria.

In India, despite the intensive pressure of population on land, areas running into millions of hectares have been left idle because of malaria or deep-rooted grasses such as kano grass, which cannot be eradicated except by modern machinery. The third five-year plan provides for the reclamation of 1,450,000 hectares now uncultivated.

Irrigation in the desert and semidesert lands

Deserts which were fortunate enough to be crossed by large rivers provided the stage for all the earliest civilizations. Such were the conditions in the valleys of the Nile, the Tigris-Euphrates, the Indus and the Yellow river. The effective harnessing of rivers that rise in mountainous areas, where precipitation is high or snow provides a permanent source, and find their way to the sea across land that receives too little precipitation for growing crops, can still make a substantial contribution to the world's food supply. In some of the older irrigation areas, misuse of water and inadequate attention to drainage have led to problems of waterlogging and/or salinity which have put millions of hectares out of use. There is no doubt that with proper methods these can be reclaimed.

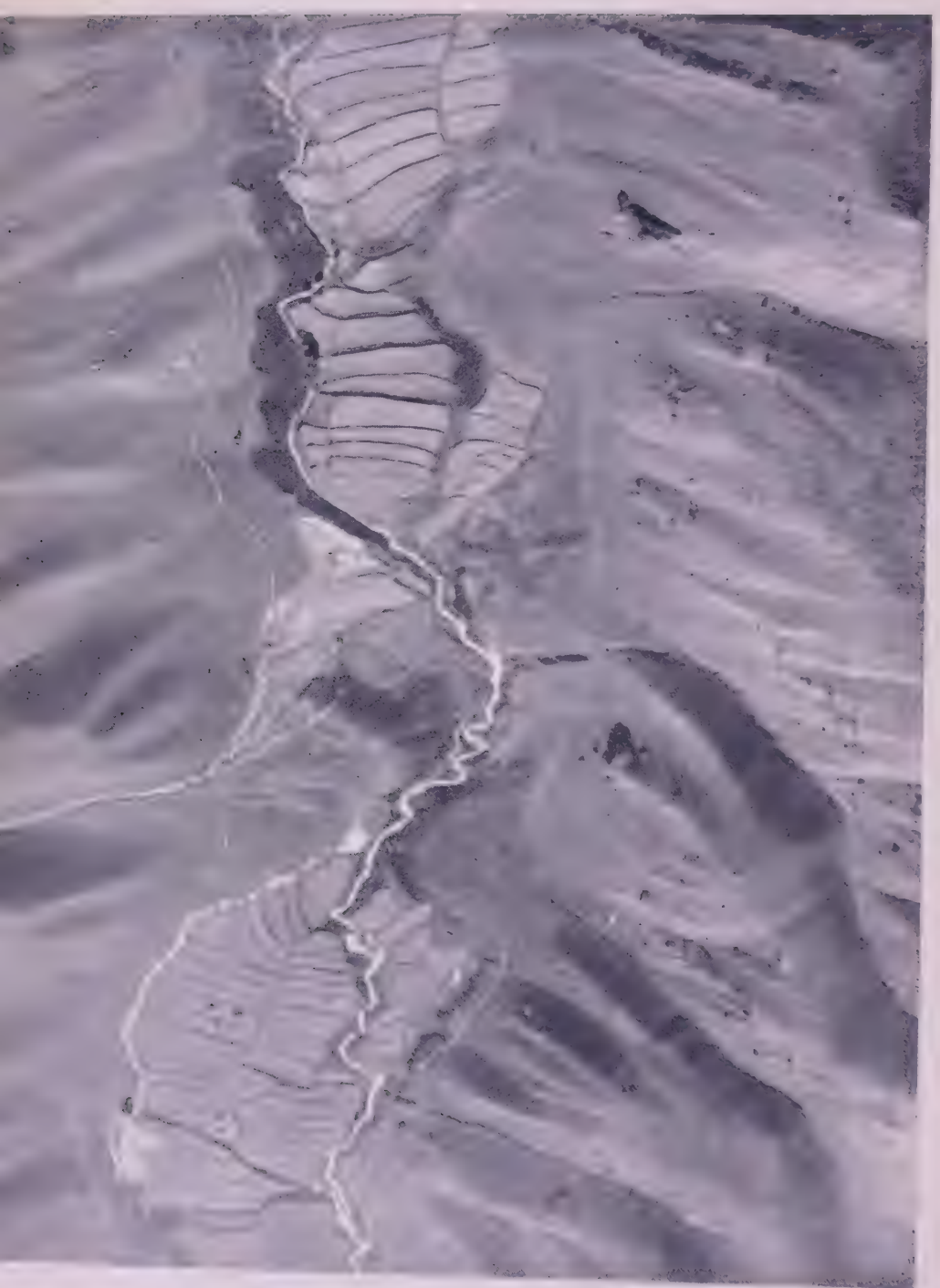

FIGURE 8. - Agriculture in the desert: irrigated land in Iran.

In the arid areas of the Near East, which for this purpose is defined as including the North African littoral east of Tunis, the Arabian Peninsula and the lands stretching from Syria through Iraq and Iran to West Pakistan, water is the absolute limiting factor in agricultural production. However, at present neither existing surface nor existing ground waters are being fully utilized. Sufficient water serves to irrigate properly the present cultivated areas, where the water duty is often quite inadequate, as well as to bring substantial areas of additional land under cultivation. However, except for the Nile, the Tigris-Euphrates and the Indus, this part of the world is lacking in large rivers and it must be recognized that the agricultural potentialities in relation to total land area will always remain very limited, unless technical progress in distillation of sea water should make it economic to draw upon the oceans for irrigation.

In the United Arab Republic, the Higher Aswan dam would, from an engineering point of view, make possible the cultivation of an additional 420,000 hectares (an increase of one sixth over the present area), while 300,000 hectares will be transformed from basin to perennial irrigation, provided that an economic solution can be found to the problem of a rising water table with surface accumulation of salt, which has emerged gradually as a result of the change-over from basin to perennial irrigation during the last century. In Iraq, there are "tremendous areas of salty land in the Tigris and Euphrates valleys" which need leaching and drainage.[40] In fact, the greater part of the cultivated area suffers from salinity in varying degrees. In the absence of an adequate supply of water and artificial drainage facilities, peasants follow a fallow system in cropping irrigated land, leaving it idle one or more years after every crop in order to allow the deep-rooted perennial plants to dry out the subsoil. The system also allows nitrogen to be built up, but sufficient only to produce low yields. If adequate drainage and more water were provided, along with a farming system designed to build up fertility and organic matter, the land could be cropped continuously in rotation with higher yields than at present, without leading to water-logging or salinity. Iraq also possesses large additional areas capable

[40] B.Y. West, *Report of the soil survey and soil classification Dujaila project, August 1955.* Baghdad, Government Press, 1955.

of irrigation, so long as this is accompanied by adequate drainage facilities and flood control.

The Indus and its tributaries water one eighth of the world's irrigated area, constituting the world's largest irrigation system. Here also, extremely serious problems have been created by misuse of water, and large increases in production could be obtained by correction of these abuses. Figures on the area involved differ, perhaps in part because of differences in definition, but all agree on the enormous magnitude of the problems of waterlogging and salinity in the Indus basin. According to the Pakistan second five-year plan, "salinity and waterlogging pose a serious threat to the national economy. It is estimated that over 50 percent of the irrigated land is affected, an area of some 12 million acres (5 million hectares). Control of salinity and waterlogging presents a gigantic problem." This problem has recently been thoroughly studied at the request of the Government of Pakistan by a team of United States scientists, who concluded that 2 million hectares of the cultivated lands (18 percent of the gross area sown in the Indus plain) are " already seriously damaged by waterlogging and salinity," and the damage is increasing annually at the rate of 0.2 to 0.4 percent of the sown area, i.e., 20,000 to 40,000 hectares per year. It has also been estimated that
25 about ~~7.25~~ million hectares have gone completely out of production through this process.

Here, as in Iraq, the first charge on the water which is not now being conserved, or which is derived from lowering the water table, should certainly be to intensify the use of water on lands already commanded but not adequately irrigated, and to reclaim those now lost rather than extend the areas under irrigation. Scientists in the United States estimate that the tube wells, which would be used to lower the water table, would make available an additional million acre feet of water for every million acres, and that drainage and more intensive use of water alone would raise production by over 50 percent. But they also advocate that the immense expenses involved in such a program — between $55 million and $165 million for each million acres (400,000 hectares), according to location, should be accompanied by the intensive use of nitrogen fertilizers and improved seed and plant protection measures. The total increases in production under this combined program is estimated at 182 percent

(i.e., nearly a tripling in output), with an increased value five times the annual cost. [41]

Salinity is also a problem in the Upper Gangetic plain, where 1 to 1.5 million hectares are reported to be affected to a greater or lesser extent out of a total of over 15 million hectares of cultivated land in Uttar Pradesh.

Elsewhere in the Near East, much attention has been given to the survey of water resources, especially ground water, but so far not enough is known regarding potentials. Projects which have been studied in varying degrees, some of them obviously ambitious and very tentative, would add up to a total of 4.5 million hectares for the whole region of the Near East and North Africa.

Of tremendous importance is the now verified existence of a vast freshwater reservoir which underlies a large part of the Sahara sand dunes. Recent research by the Service de l'hydraulique of Algeria shows that the Albienne Nappe stretches for over 800 kilometers south from the Atlas ranges and it may also extend under Tunisia and the deserts of the Fezzan in Libya. The layer of water which is estimated to be up to 1,000 meters thick, absorbs at least 1,000 million cubic meters of water per year from the Atlas rains. Another large underground reservoir stretches north from the Ennedi hills in French Equatorial Africa toward the United Arab Republic, reaching the Qattara depression near El Alamein. Utilization of these waters, which are replenished from the heavy rainfalls enjoyed by mountainous regions to the northwest and south of the Sahara, may ultimately transform a part of what has always been regarded as the desert par excellence of the world.[42]

Water resources will permit of substantial increases in irrigation in the semiarid and arid lands of the western United States, Mexico, Peru, Chile and Argentina. In the United States, more than 10 million hectares had been provided with irrigation in the desert and low

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[41] See the following references : Government of Pakistan, *The second five-year plan* (1960-65), p. 209, and *Report of the Food and Agricultural Commission*; also, Pakistan to reclaim its water-logged land, in *Foreign Agriculture* (United States), October 1961. The report of the United States scientific team referred to above is not yet available in printed form.

[42] See UNESCO, *Arid zone hydrology*, 1953, p. 17-18; also Ritchie Calder, Walking on water. *New Statesman and Nation*, 15 May 1954.

FIGURE 9. - A wheat field in the Sahara. The recent discovery of artesian water under the Sahara gives a completely revised picture of the future development of the region.

rainfall areas of the west by 1953, but the Bureau of Reclamation reports that water was available for an additional 6 million hectares that might be developed in the future.[43] Since then, two major projects under way in the Columbia and Missouri basins are adding 2 or 2.5 million hectares of irrigated land. Some, but by no means a full, indication of the potentialities for irrigation in Latin America is given by the fact that irrigation projects studied, planned or under construction in the various countries in 1953 totaled 4.2 million hectares of mostly arid and semiarid regions.[44]

In Australia, although water resources are very limited, reservoirs under construction or planned will increase substantially the area capable of irrigation. According to a survey in 1954, reservoirs in construction in New South Wales and Victoria would more than double the then existing capacity of dams, which were providing irrigation for 505,000 hectares.[45] By 1960, the irrigated area in these two states had risen to 700,000 hectares.[46] The irrigation potentials for Queensland, which exceed those of any other state,[47] are still practically untouched, with a total area under irrigation of less than 80,000 hectares.

The greatest unutilized possibilities for providing water for steppe and desert soils appear to exist in the U.S.S.R., where 6.5 million hectares were reported as irrigated in 1950 [48] and 12.4 million hectares were provided with irrigation facilities in 1960.[49] Some indication of the irrigation potentials was given by the series of major projects announced by the Soviet Government in October 1950 for irrigating the arid and semiarid regions in the south from the waters of the Volga,

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[43] J.E. Christiansen, Irrigation in relation to food production. *Agricultural Engineering*, June 1953.

[44] N.D. Gulhati, *Irrigation in the world*, International Commission on Irrigation and Drainage, Delhi, 1955.

[45] K.A. Murley, Organization for the development of water resources in Australia. *Proceedings of the Regional Technical Conference on Water Resources and Development in Asia and the Far East, Tokyo, 1954*, Bangkok, U.N., p. 418-422.

[46] Private communication from the Bureau of Agricultural Economics, Canberra.

[47] See footnote 45, same conference.

[48] N. D. Gulhati, *Op. cit.*

[49] Unpublished report of FAO Group Fellowship on Irrigation and Drainage Practices, held in the U.S.S.R., 1961.

Dnieper and the Amu Darya. In the case of the latter, a large part of the flow was to be diverted from its outlet in the Aral sea and brought across the Karakum desert to the Caspian. The five major projects involved something in excess of 6 million hectares for intensive crop production, as well as provision of water at a lower rate of duty for a more extensive area of pastureland.[50] The figures above suggest that most of this work has been executed.

Probably the most dramatic of all projects, and that with the largest reported potentialities, is the Ob-Yenisey project, which envisages the diversion of about 12.5 percent of the water that flows to waste into the Arctic Ocean to water the steppes and deserts of the western part of the Asiatic U.S.S.R. The plan of the engineer Davidov, which appears to have now received official approval, calls for an immense dam on the Ob, just below the junction of the Irtish, which would create an inland sea approximately five sixths the size of Italy. By means of a series of canals connecting various lakes and river beds, the water would be brought across 4,000 kilometers of arid land toward the Aral sea. The water supply would be supplemented by another canal connecting the Yenisey with the Ob. It is proposed to use the immense volume of water which would thus be made available to irrigate 25 million hectares for crops and a somewhat larger area for pastures.

Substantial possibilities for irrigation of desert areas, running into several millions of hectares, exist also in northern China, principally from the waters of the Yellow river.

Although the total area of arid and semiarid lands capable of being brought under irrigation is small relative to the areas of potential farmland in the tropics, one must remember that yields under irrigation are high and assured. The problems involved in bringing desert lands into cultivation, provided water is available and the topography suitable, are also small compared with the problems to be faced in either the continuously wet or the alternately wet and dry tropics. Perhaps the principal requirement, from an agricultural point of view, to ensure permanent exploitation, is to learn the lessons of the Indus and Tigris-Euphrates valleys, as well as numerous other

[50] A.A. Grigoryev, Soviet plans for irrigation and power: A geographical assessment. *Geographical Journal*, June 1952.

irrigation projects in arid areas over the world, by ensuring both adequate drainage to prevent excessively high water tables and sufficiently heavy water use to wash downward the salts brought in by the irrigation water.

Finally, in considering the potentialities of arid lands, one should not entirely overlook the possibility that sea water may some day become available for irrigation on economic terms. Research carried out in the United States, Israel and elsewhere has recently succeeded in reducing substantially the cost of distillation of salt water, and the possibility is by no means to be excluded that improvement of existing techniques or development of new processes may reduce the cost to a level which would be economic for irrigation purposes.

The possibilities of extending cultivation in the well-watered temperate lands

Contrary perhaps to general belief, by no means all the good rainfall country in the temperate zones of the world has been brought under the plow, although opportunities in the Northern Hemisphere are very limited indeed. In the Southern Hemisphere, however, two major zones where climatic and topographic conditions appear well suited to agriculture have remained grazing areas on a fairly extensive basis — the higher rainfall areas nearest the coast in eastern and southern Australia and the lands to the north of the La Plata delta in Uruguay and southern Brazil. Probably in both cases but certainly in Australia, unrecognized soil deficiencies have been the main factor, though a land-ownership pattern favoring a pastoral way of life, associated with low population pressure, has certainly militated against attempting to remedy this problem in Uruguay and southern Brazil.

Compared with the equatorial and savanna lands, relatively easy opportunities for expansion of the cultivated area are to be found in the temperate zone in Australia, where the early settlers passed over extensive areas of good rainfall country, because of the poverty of the soils, to farm what is now the wheat belt, where rainfall is more precarious but the natural fertility of the soils was considerably higher. The areas to the east and south of the wheat belt have remained essentially pastoral, with predominantly unimproved pastures and

FIGURE 10. — England : harvest in the Cotswolds. In the Northern Hemisphere, most of the good rainfall country of the temperate zone is fully exploited, but in the Southern Hemisphere, substantial areas await development.

low carrying capacity. A considerable part is in scrub or forest of little or no value for timber.

Recent research has shown why the pioneers could not utilize these lands. These old soils are usually deficient in one or more trace elements and universally lack nitrogen.

In the attempt to find out precisely why " every attempt by humans to grow food in these low fertility lands of better rainfall has failed dismally... the breakthrough came in the decade 1930/1940 as a direct result of agricultural research in which knowledge of plant physiology and plant nutrition were applied to our climatic and soil conditions. The discovery of the essentiality of molybdenum for plant growth was a direct and very important addition to scientific knowledge." [51]

In his presidential address in 1952 to the Australian Institute of Agricultural Science, Dr. Davies pointed out the future course of development of these areas: (*i*) the addition at little expense of the combination of elements found to be lacking; (*ii*) raising the nitrogen and organic status of the soils through leguminous pastures; (*iii*) a diverse cropping regime based upon a rotation of pastures, cereals and other crops. " It is only necessary to define which combination of elements is in deficiency to transform these lands into fertile farms."[52]

Davies estimated the extent of the " reasonably well-watered land" of southern Australia (i.e., excluding Queensland and the Northern Territory) at around 100 million hectares, of which less than 12 million were under crop or fallow, just over 4 million carried improved pastures, and about 8 million were in forest. (The area under improved pasture in Australia has now risen to 13.7 million hectares. This has not, however, been reflected in an increase in grain acreage because of export market limitations.) Of the residue of about 81 million hectares, Davies deducted 20 percent for rough terrain or land required for other purposes, leaving an admittedly rough estimate of 60 million hectares awaiting improvement through the methods he has outlined, an area four times that then used for cultivation or improved pasture.

[51] J. Griffith Davies, private communication.

[52] J. Griffith Davies, Presidential address to the Australian Institute of Agricultural Science, 1952.

Opinions are more divided regarding the potentialities and best patterns of land use in what have so far been the predominantly grazing areas in the southern part of Rio Grande do Sul (Brazil) and in adjoining Uruguay. The region has a rainfall of 1,000 to 1,250 millimeters, well distributed throughout the year, but unfortunately with a high annual variability. The good rainfall combined with a warm temperate climate has provided excellent natural pastures. Its natural endowment probably fits it for considerably more intensive use, but the variability of the rainfall and the shallowness of the soils in many parts constitute serious impediments to the transition from the traditional system of use based mainly on grazing of the natural pastures, to a system consisting predominantly of mixed farming with pastures, livestock and rotational crops, which would of course be far more productive where it is technically and economically possible. On the other hand, there is little doubt that the system of land tenure and the outlook of the ranchers (the "hidalgo" philosophy), together with the absence of pressure of population on resources, has been an important factor in the continuation of the present system of land use.

James, with his keen eye for the impact of cultural values on land use, writes of Rio Grande do Sul: " Whether these southern prairies can be utilized for the production of Brazil's supply of wheat depends more on the success of a campaign to transform the way of living of the gaucho than on the physical quality of the land. In the absence of detailed studies of soil and moisture, it would seem probable that, with an entirely different agricultural system, which probably means different people, the prairies of the South could be made to support a much denser population on the basis of a farm system not unlike that of parts of the North American Corn Belt." [53]

Contrary views are, however, held by Davies on the basis of his experience in Australia: " The importance of land tenure and the ' hidalgo ' philosophy is not minimised by recognising that in these two regions there is a dearth of knowledge regarding soil nutrient deficiencies. This was obvious to me on my visit through these lands last year. Both Rio Grande and Uruguay are in the same stage of scientific knowledge of their pastures and pasture soils as Australia was in 1900-1930. It is this lack of knowledge of how to apply the

[53] P.E. James, *Latin America*. New York, Odyssey Press, 1942, p. 526.

well-known facts of soil chemistry, plant nutrition and plant physiology that underlies the form of pastoral agriculture." [54] FAO experts in Uruguay (Moir and Reynaert) have also established that phosphorus is very generally deficient in the soils, and in fact many farmers apply phosphate top dressing to pastures in Uruguay.

In Uruguay, the cultivated area has fluctuated between 4 and 13 percent of the total area for the last 60 years, although, according to James, only a small proportion of the country is physically unsuited to the production of crops. Here again, Davies would nevertheless place the main emphasis on remediable soil deficiencies: " The prime deficiency is not the people but the low nutrient content of these soils. This precludes the growing of crops for more than a year or two except in isolated pockets." It is Davies' view that, as in extensive areas of Australia," it is only necessary to define the combination of elements in deficiency to transform these lands into fertile farms."

A third view is still more pessimistic, considering that shallow and rocky soils, that should not or could not be cultivated, comprise between 40 and 50 percent of the land area and that not more than 15 percent of Uruguay is excellently fitted for crops. This school also considers that crop production in much of Uruguay and southern Brazil is risky because of either too much or too little rainfall. Establishment of cultivated pastures is also difficult, since droughts during the seeding period (autumn) often prevent establishment of the pastures. Alfalfa did not spread in Uruguay as in the pampa of Argentina, due to differences in soils — depth, fertility, texture — and climate. (The pampa has a more consistent summer rainfall.) The most important difference, however, is in the soils, since in areas of loess deposits in Uruguay alfalfa grows well, just as in Argentina. These experts agree on Davies' emphasis on mineral nutrition, but feel that one should not overlook the fact that many of the soils are extremely shallow and others have such heavy texture that drainage is a serious problem in southern Brazil, Uruguay, and also in the adjoining areas of northeastern Argentina.[55]

In terms of long-term potentialities, the truth probably lies somewhere between the extreme optimism of James and the most pessimistic

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[54] Private communication cited above.

[55] Vallega/Peterson, private communication.

views which stress the immediate difficulties, which could certainly be ameliorated by research into mineral requirements of the soils and the production of pasture and crop varieties suitable to the more difficult climatic conditions. The historical and sociological factors have undoubtedly been a major element in the continued dominance of a grazing industry based mainly on natural pastures. The persistence of a purely pastoral economy in this area is also to be explained in part by "lack of knowledge of how to apply well-known facts of soil chemistry, plant nutrition and plant physiology," as stated by Davies. A third factor is constituted by the shallowness and texture of the soils over a considerable part of the area and the uncertainty of the rainfall. Further resource surveys and continued research are needed before it can be known to what extent a system of mixed farming based upon the integration of crops and livestock is potentially possible in the area and to what extent the pastoral economy must continue, with intensification through greater use of cultivated pastures, improved natural pastures, and better management.

Should economic conditions require it, there is no doubt that strong possibilities for expansion of the cultivated area also exist in Argentina. Despite the large quantities of cereals and oilseeds produced, the proportion of land devoted to permanent pastures is never less than 40 percent even in the most intensively farmed districts, and in some parts rises as high as 90 percent. The southeast, between Buenos Aires and Mar del Plata, where considerable drainage would be necessary for large-scale agriculture, remains almost exclusively pastoral.

The northern podzolic soils

Another region to which attention has been drawn, particularly by Kellogg and Salter, as a potential area for extending cultivation, is the podzolic zone to the north, principally in the U.S.S.R., and to a lesser extent Canada. As already noted, Kellogg considers, on the analogy of Scandinavian and Finnish experience, that some 10 percent of these soils, amounting to about 120 million hectares, might ultimately be used. In Canada, Leahey places the reserve of arable land at about 18 million hectares, or approximately half the area now under cultivation. It is also thought that the area which could be utilized

FIGURE 11. – A Swedish farm: part of the 1 percent of the land to the north of the temperate zone at present under cultivation. It is estimated that the parallel development of transport, industry and agriculture in such regions could bring 120 million more hectares under crops.

for permanent pastures is about 40 million hectares as against 20 million hectares so used at that date.[56]

Even in Japan, the government classified 1 million hectares as awaiting reclamation for crop production. Two thirds of this is in the extreme northern island of Hokkaido, where much of the unreclaimed area consists of peatland.[57]

In the final analysis, it is improbable that extension northward of the frontier of cultivation will offer to the world any large proportion of the benefit to be gained by bringing the tropics under domination, since the environmental conditions for growth in the high latitudes are much less favorable, due to lower natural fertility, than are those of the tropics and, in addition, suffer in many regions from seasonal or permanent excesses of moisture, since the slow rate of evaporation does not in many regions adequately balance the precipitation, low though it may be. Special methods of cultivation to increase aeration, to give higher soil temperatures in the spring, and to permit higher infiltration rates in the relatively dry summers are necessary.[58]

In much of the glaciated northern regions, the presence of numerous boulders and of undrained depressions with peat and bog soils in the areas of glacial till represent additional problems requiring extensive outlays of labor to bring the land into production. In the European part of the U.S.S.R., it is estimated that there are 11 million hectares of potential arable land requiring stone removal, in addition to the areas too stony to make clearing economic (Grigoryev).

The management of the podzolic soils will require a mixed farming system, with a high proportion of livestock to permit the improvement of soil fertility through the utilization of forage crops. The problems of providing shelter and winter care for these animals repre-

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[56] A. Leahey, Agricultural soil resources of Canada. *Agricultural Institute Review*, Vol. 1, No. 5, May 1946; see also E.S. Archibald, Agricultural lands in the Canadian Northwest. *Canadian Geographical Journal*, July 1944. More recent detail is given in A. Leahey, Appraisal of Canada's land base for agriculture. *Background papers for Canadian Conference on Resources for Tomorrow* (1961), Vol. 1, p. 49-54.

[57] Shiro Sasaki, *Land development and improvement projects in Japan*. Japanese Ministry of Agriculture, Forestry and Fisheries, 1959.

[58] See, for example, A.A. Grigoryev, Reclamation of the forest belt of the U.S.S.R. in Europe. *The Geographical Journal*, December 1953, p. 411-419.

sent another disadvantage for the region. However, with the development of mixed farming based upon adapted cereals, forage crops and a dairy industry, and with the use of substantial amounts of lime and mineral fertilizers, the podzolic region can be expected to give a fairly large production of those crops and animal products for which the abundant potential resources of the tropics are not so suited.

It must be recognized, however, that the development of the northern podzolic region requires not only a heavy initial investment to prepare the land for cultivation but also a heavy continuous use of labor, fertilizers and forage crops to produce a surplus for sale. The additional supplies of food possible under these conditions will not be obtained cheaply in terms of human labor or its cash equivalent.

3. POSSIBILITIES OF INCREASING CROP YIELDS

It is generally recognized, except perhaps by those who take the very gloomiest view of the future of the human race, that very substantial possibilities exist for increasing the production of food and other agricultural products from the arable and grazing lands now in use. Such increase may be obtained by raising the yield of crops and pastures per unit of land area and by achieving greater production of animal products per unit of feed consumed. For the most part, the investment and the fundamental research which would be involved in the realization of these potentialities would be far less than that needed for bringing new lands under cultivation. Nevertheless, the research and expenditures required are large and particularly burdensome for those countries where the greatest possibilities exist.

It would be unfair to the reader to plunge into a subject so wide in scope and with so many ramifications, without some preliminary remarks regarding the method of treatment. The method of treatment is perhaps a writer's private problem but mention of some of the difficulties may help to explain the imperfections and signs of strain which will be all too clear to the observant reader. The first problem of method is how to organize the material in a subject in which every aspect is connected to many other aspects in a network of interdependencies; the second is how to find an approach which will permit of at least a measure of quantitative judgment regarding possibilities which we all know to exist in a general way. The next few paragraphs are, therefore, devoted to these preliminary questions.

While it is technically most acceptable to describe the concept of increasing yields in terms of crop and pasture output per unit of land and livestock efficiency per unit of feed, as has been done in the opening paragraphs of this section, in practice it seems more conven-

ient to discuss firstly the subject of crop yields from arable farming and, secondly, the possibilities of increasing the output of animal products through (*a*) an increase in the number of head that can be carried effectively; and (*b*) an increase in the productivity per animal.

In respect of the livestock-carrying capacity, the whole subject of pasture improvement is of overwhelming importance. It must be recognized, however, that the two subjects of increasing crop yields and raising the output of livestock products are very closely related. Apart from the fact that some of the feed supply for livestock comes from arable lands and that pastures may be part of a rotation on such lands, a close integration of crop and animal husbandry in a system of mixed farming is generally best for maintaining soil fertility and results in the highest productivity for both crops and animals. Furthermore, an increase in the yield per hectare of food crops, particularly cereals, for direct human consumption, may release part of the area previously devoted to these crops for producing animal feeds. This is, in fact, a historical process of the utmost importance in diversifying both agriculture and human diets.

In connection with increasing the yield of crops per unit of arable area, one may consider the conservation of soil and water, the better use and control of water and improved drainage; building up soil fertility through use of legumes and good crop rotations, the proper integration of crop and animal husbandry, the full use of organic wastes as manures, application of inorganic fertilizers and liming; increase of the biological capacity of plants and of their resistance to diseases, pests and adverse climatic factors by breeding; better cultural operations, e.g., preparation of the seedbed, subsequent cultivation, control of weeds and more timely operations, both of which can be greatly aided by improved types of tools and implements and, in some cases, by use of tractor-drawn equipment; improving crop rotations; control of plant pests and diseases; reduction of losses during harvesting; and, finally, though it is not properly part of the subject of increasing crop yields, reduction of postharvest losses. The principal means for livestock improvement comprise the improvement and better management of pastures, including conservation of fodder; provision of facilities for water; control of animal diseases, external pests and internal parasites; making the maximum use of available feed through scientifically balanced rations; and, finally,

FIGURE 12. – Building an earth dam in Togo. Earth dams can also be built by farmers using simple equipment and local material.

raising the biological productive capacity of the livestock and breeding animals which combine high productivity with resistance to unfavorable climatic conditions, e.g., the tropics and subtropics.

In the present document, an attempt is made to discuss these subjects seriatim. There is, however, a high degree of interdependency between the various technical means for increasing yields. For instance, higher-yielding varieties require heavier fertilization; the economics of irrigated farming may require better varieties and heavier use of fertilizers; fertilizers may call forth an adequate response only if varieties are improved and/or more moisture is provided; weed control becomes more important with better varieties, since the total demand on the nutrients in the soil is greater; mechanized harvesting is frequently impossible until the plant breeder has produced varieties which shatter less easily. On the livestock side, breeds with high biological capacity can yield well, perhaps even survive, only if better fed than the scrub animal; while a response to better feeding will not be obtained, beyond a limited range, unless the inherent productive capacity is raised; both upgrading and improvement in feeding are largely a waste of effort unless epidemic diseases are brought under control. Above all, there is the superiority, under most conditions, of mixed crop and animal husbandry as against either separately. Some of these interrelationships are mentioned in subsequent paragraphs where they are most pertinent, but it is important to keep them in mind during discussion of the individual technical factors. The technical relationships mentioned above are, in fact, merely specific illustrations of the general economic law that continued inputs of additional units of one factor of production, while other conditions are held stable, will always result in diminishing marginal returns per unit of input.

The previous paragraphs have indicated one broad approach to the whole subject, namely, to start from the various technical methods of increasing crop and livestock productivity, consider the extent to which they are at present being utilized, and attempt to evaluate the contribution that the wider application of these methods might make to increasing per unit yields. This approach can be illuminating in suggesting how varied and how tremendous are the opportunities, and can, by means of a few well-chosen examples, give some indication of the magnitude of the results which might accrue. However, from

the point of view of measuring potential results, it suffers from the handicap that while the technical methods require to be treated separately, the full effect on yields comes only from the combined application of improved techniques. One cannot, therefore, go far in measuring potential benefits from individual lines of progress, such as greater use of fertilizers or use of improved varieties. Even if this were not so, it would be only rarely in our present state of knowledge that we could indicate even roughly the potential gain in productivity per unit of land or livestock that might accrue from a particular technique under specific geographical conditions. The whole approach therefore is necessarily a rather general one and remains weak on the side of quantitative assessment.

An alternative approach, which lends itself to measurement but can be very dangerous if used without adequate knowledge of the ecological and economic factors governing production in different regions, would be to consider the yields which have been achieved in the more advanced countries in each particular branch of farming and, with due allowance for the existence of exceptionally favorable circumstances or levels of input which might not be economic in some other countries, take this as a rough measure of the possibilities in other parts where natural conditions are more or less the same. The problem in this approach is to distinguish between the extent to which, or the instances in which, high yields are due on the one hand to either better natural conditions or uneconomic levels of input and, on the other hand to better farming. Obviously, this can only be done imperfectly but it is not difficult in many cases to hazard an informed guess on which of these factors is the principal element in yield differences. This judgment may be the more easily made where historical data are available on yield trends and these can be compared with changes in farming practices.

In addition to differences in average yields between countries, much light can be thrown on yield potentialities by noting the differences in any country between average yields and those obtained from the best or good farming practices.

The great advantage of approaching the subject from the side of results instead of causal factors is that the results sum up the *combined* effect of improved agricultural techniques. But as mentioned above, they also reflect differences in natural conditions or uneconomic

inputs, so that here again there is no substitute for an adequate knowledge of the technical and economic aspects of farming in the regions or countries compared. Because of limitations on our present knowledge, it is once again necessary to confine the treatment to examples, though some of them are of very broad significance.

The most fruitful approach appears to be a combination of both approaches, and it is this combined attack that it is proposed to follow.

Technical measures for increasing productivity

In the following pages, an attempt is made to point out wherein lie the chief technical possibilities for increasing crop yields, with some indication of the magnitude of the contributions that could be made by the various improvements in farming methods. Special attention is given to the conservation of soil and water resources, use and control of water, building up soil fertility, plant breeding and seed improvement, better equipment, improving crop rotations, reducing losses caused by diseases and pests in growing crops and stored products.

Conservation of soil and water

Conservation of the basic natural resources of soil and water is an essential preliminary for raising yields. Conservation of these resources is not mainly a matter of engineering works, as is often supposed, though engineering has its part to play; *resource conservation is fundamentally a matter of wise resource use in accordance with the ecological conditions.* Some stress should be put on the word use, because there is another fairly common misconception that somehow use and conservation are opposites. Unfortunately, where resources have been overexploited for too long, the soil itself, or at least its fertility, may be lost for ever. In milder cases of overexploitation, a period of rest may be necessary. In general, however, good land use is not only compatible with, but is an integral part of, conservation. In the long run, it is even likely to result in an increase over the native productive capacity of the resources, especially in the case of soils.

The emphasis on potentialities in the geographical regions distinguished in Chapter 2 should not be allowed to obscure the fact that

every year large areas of land are lost for every kind of valuable production through misuse. It is difficult to measure the extent of this loss, which is usually related either to overgrazing or to shifting cultivation. The most serious form of shifting cultivation is not that of the old tribal type, with which this term is usually associated, and which is rather conservative as long as population pressure is not too heavy, but the shifting cultivation caused by land hunger of farmers whose farms are too small or who are without land (e.g., in the Philippines, India and throughout much of Latin America). For example, it should not be forgotten that coffee cultivation in Brazil (mentioned later in this section) is really shifting cultivation, which may result in the complete disappearance within a decade or so of the only valuable stands of softwood trees in South America.

The soil erosion associated with declining productivity of land also has very serious effects through the transportation by water of solid material which subsequently clogs canals and silts up reservoirs. There is thus a close connection between misuse of land in the hills and mountains and the possibilities for intensive agriculture on the plains.

Good land use always implies balanced land use — a balance between the production of food for direct human consumption and feed for livestock on the arable land, and a balance between arable land, natural pasture and forests. If there is imbalance between the areas devoted to food and fiber crops and the areas devoted to animal feed, because inadequate place has been given either to improved pastures or to grasses and legumes in the crop rotations, the livestock industry cannot be integrated with agriculture in a pattern of mixed farming. In this case, it is either neglected or creates undue pressure on the natural range and forest lands, with an overloading of goats, sheep and cattle which these lands are unable to bear without deterioration of the soil.

Even in well-developed areas, the complete absence of trees and forests has unfortunate consequences. The lack of wood and timber for the rural population compels people to use dung as fuel for heating and cooking which should be used as manure (see section on improving soil fertility, p. 96). The lack of wind belts also favors wind erosion and leaves agricultural crops without adequate protection against the drying effect of winds. On the fringe of deserts, as well as on sea coasts, the formation and advance of dunes is taking away

from cultivation an area which is far from negligible. Examples of good practices from this point of view may be mentioned in Pakistan (irrigated plantations), in the Nile Delta (line plantations along the roads and canals) and in the U.S.S.R., which has particularly extensive experience of the effects of wind belts on crops. Far from entailing a decrease of revenue for the farmer, tree plantations, if they are made under good techniques and with the appropriate species, may also add considerably to his revenue.

Two rather specific examples of needs and possibilities in the field of soil and water conservation are given in the remainder of this section. They are drawn from very different conditions and consequently illustrate quite different methods.

Water conservation in Somalia

Somalia is an arid country lying on the northern edge of the Horn of Africa. There are no permanent rivers, and the 250 to 300 millimeters of rain all fall in the summer months in occasional rainstorms, which cause numerous gullies which dissect the whole area. The bulk of the country is used by nomadic flocks and herds of sheep, goats, camel and cattle, though within the last two or three generations sorghum cultivation has become increasingly important, with some maize and melon growing.

Over 90 percent of the farmland area is subject to sheet and gully erosion. As the result of excessive grazing, there is little absorption of rainfall, hence run-off creates a serious problem. Various systems had been tried with indifferent success, and it became increasingly obvious that some form of earth banking to make the maximum use of available water and to control erosion was necessary. Such a system would have to be aimed at preventing the growth of gullies rather than depending upon them.

Two such systems were developed and these are now in common use throughout the country — their only essential difference being the way in which they deal with the overflow. They were developed in different areas and evolve from differing geographical conditions and availability of materials. Both systems are essentially a series of earth banks, built to a height of 1 meter and ranging in length up to about 110 meters, with a distance of 13 to 27 meters, or vertical intervals of 45 to 60 centimeters between banks.

The Borama system was developed in the west, where rainfall is higher and stones more readily available, and where farms are generally in small valley bottoms receiving run-off from the sides. This system uses earth banks with extended arms with an angle of 45°, which have no other function than to contain water. These arms are carried to within 9 meters of the contour line of the bank (or bund) above, allowing a safety valve for exceptionally heavy floods. The bunds are interrupted every 27.5 meters by a stone spillway; none of these openings is directly above or below another, thus allowing greater water dispersion.

The Hargeisa system, which was evolved in an open, gently sloping plain and broad valley area with less rainfall, coarser soil and scarcity of stones, does not employ stonework. These earth banks are in the form of gentle curves, again up to 110 meters in length, from 13 to 27 meters apart. Present practice allows a shallow spillway at the ends of the arms which leads surplus water around the arms without touching them. This water then enters the next area through a graded channel just below the spillway, which, in addition to turning the water into the lower area, makes full use of the run-off water. Such water from uncultivated adjoining land may well amount to two or three times the quantity actually falling on a farm.

This system can in a bad season make the difference between a crop and no crop, and in a good year can substantially increase the yield, while also protecting the land from erosion. The system works almost automatically and requires only a minimum of maintenance.

Coffee in Brazil

In Brazil, coffee has in the past been a constantly moving crop, as it was cheaper to shift plantations to neighboring virgin land than to try to maintain production on overworked soil. This situation was aggravated by the abandonment of large coffee areas because of world overproduction.

The availability of this virgin land is now rapidly drawing to a close and, although the bulk of production still stems from recently deforested land in Paraná, attention has turned to the possibilities of rehabilitating coffee production in selected " old " zones in São Paulo. Largely through the auspices of the Instituto Agronomico de Campinas,

at São Paulo, a number of plantation owners have adopted good soil conservation practices and have started such rehabilitation programs with satisfactory results. Research and experimental work is sufficiently advanced to guarantee the success of such enterprises. In fact, even with a considerable reduction in total coffee-growing area, yields have been maintained, and have at times been surpassed.

A majority of the coffee plantations in Brazil are established on the deep " terra roxa " soils which occur in large areas of São Paulo and northern Paraná. These are known as the " coffee soils " and are among the most productive in South America, giving high yields of coffee. Production declines, however, after a few years, mainly due to the loss of organic matter in the soil through oxidation, leaching and erosion. Extensive coffee plantations have also been established in sandy soils in northwestern São Paulo and on " red-yellow latosols " in São Paulo, Minas Geraes, Rio de Janeiro and Santa Catarina.

Much experimental work has been conducted in these coffee areas to show the extent of the soil loss in coffee orchards under various management practices. On an average, it has been found that the annual loss by erosion amounts to 2 tons per hectare where there is no cover, compared with 0.002 ton where the same soils are under forest, and 1 ton when under pasture. In addition to showing soil losses, experiments have also revealed, for example, that the amount of plant nutrients actually removed by erosion from "terra roxa" soils, cultivated for 22 years with coffee, were 50 percent nitrogen, 37 percent phosphorus, 93 percent potassium and 80 percent calcium.

These investigations opened the way to a wider use of soil conservation and management practices among the farmers. These practices, such as the efficient use of fertilizers and sprinkler irrigation, are being introduced not only on recuperated old lands but also on recently opened areas.

Vegetative practices have proved highly efficient in reducing soil erosion. Soil cover and green manuring usually give excellent results. Soil cover with *Canavalia ensiformis* and *Tephrosia candida* can reduce erosion losses by as much as 50 percent. In areas where there is widespread erosion, the use of mulches is reported to have reduced soil losses up to 65 percent.

Mechanical practices, such as coffee planting on the contour and terracing, are now being widely used. Experimental work has indicated

that the amount of soil lost yearly decreases from 2.2 tons to 0.29 ton per hectare where terraces are used. Even in contoured lands, the sandy soils, comprising most of the coffee area in São Paulo, are liable to erosion under the impact of driving torrential rains common to these areas. Efficient erosion control measures include the use of grass mulches. Contour ditches have been established in older plantations and coffee is planted on individual terraces on very steep hillsides. Strip weeding and the planting of contour hedges have also been carried out. This new phase of coffee production, based on good soil conservation practice, is becoming of increasing importance, not only to the large farms on recently deforested land in Paraná but also on the rehabilitated older areas of coffee production. The tendency toward decrease in size of farms and gradual exhaustion of virgin soil will make these new techniques of intensive growing of paramount importance.

Use and control of water

The provision and control of water is important for its own sake and to provide favorable conditions for other improved practices. For instance, full response from improved varieties and heavier fertilization will often require better control of soil moisture conditions. Either or both irrigation and drainage may be necessary to provide these desirable moisture conditions for the growing crops.

We do not consider here the use of water for irrigating new lands, or the drainage of swamp areas, since these possibilities have been dealt with in the first half of the paper on extending areas under cultivation. We are concerned rather with obtaining higher yields, firstly from existing irrigated areas in arid and semiarid regions by using the optimum quantities of water, wisely applied, or by better drainage; secondly, by the use of supplementary irrigation in humid and subhumid regions, on lands now under cultivation but depending entirely on rainfall; and thirdly, better drainage of nonirrigated cultivated land in humid regions or low-lying areas.

Throughout the arid and semiarid regions of the world great possibilities exist for raising yields through more intensive and better use of water on, and more adequate drainage of, irrigated land. In many of the older irrigated areas of the world, particularly in India, Pakistan and Iraq, irrigation developments are based on a very high

duty of water, i.e., a large area of land served per unit flow of water. In West Pakistan, for example, the available supplies are usually barely sufficient to irrigate adequately one third of the commanded area during any one season, and much of the land lies fallow for one or two seasons out of every three. Consequently, a two- or threefold increase in production could be achieved by augmenting the size or number of the channels and the water supply available within the commanded area.

Insufficient application of water also has most detrimental effects on the soil. Under conditions where the water table is near to the surface, as it is in large parts of the Indus valley, evaporation of moisture rising by capillary action causes salts to concentrate at or near the surface of the fallow land, and in time causes some of it to become too saline. Thus in India, Pakistan, Iraq, and to a lesser extent in all countries of the arid and semiarid Near East, yields are seriously affected by the fact that such practices, along with insufficient drainage, have resulted in excessive soil salinity over extensive areas. In the Punjab, for instance, salts are visible in patches of varying sizes on the surface of an estimated 3 million hectares, more than half of the total irrigated area. In addition to lowering yields, this has put much land out of cultivation and some thousands of hectares are being added annually to this category.[1] Very extensive areas in the Tigris-Euphrates valley are similarly affected.

The problem of deterioration of irrigated land is one of serious proportions throughout the arid and semiarid parts of the world. It is a problem requiring the immediate and most serious attention of all countries concerned. A program designed to halt further deterioration and even to reclaim all or parts of the potentially productive lands now out of cultivation has been undertaken in Pakistan with FAO assistance.

Correction of the problem is not only a matter of providing more adequate drainage or of applying an occasional heavy irrigation for purposes of flushing salts from the soil. In most cases, it will involve

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[1] A.G. Asghar, The problem of salinity and alkalinity of soils and its solution. *Proceedings of the Fourth Pakistan Science Conference, Peshawar, 1952*, Part IV; *Report of the Pakistan Food and Agriculture Commission, 1960*; and *Asian Review*, July 1961.

a combination of several measures. Since the conditions and practices which are responsible for the existence of the problems vary from country to country and often from area to area within a country, the improvement measures will similarly need to be varied.

Given an adequate supply of water and effective drainage, the technical conditions would be laid for other forms of agricultural improvement in these old irrigated areas and the resulting increases in production could often be of a very high order of magnitude indeed. It may be estimated that in the Indus valley, if efficient irrigation could be effected on the whole of the commanded area, this, together with higher yields through better drainage and reduced salinity, accompanied by improvements in fertilizer practices and varieties, could increase production within the present areas about fourfold.

In many arid areas where the supply of irrigation water is extremely limited, the most important thing is to make the maximum use of the water. In Cyrenaica, for instance, it has been demonstrated that the water, which is obtained from wells, can be made to go much further by the use of prefabricated cement canals placed along the contour lines in lieu of the traditional dirt canals. The farmer who first made his land available for this experiment has stated : " I used to draw 15 *dalos* (buckets) before the water reached my crop. It was all absorbed on the way by the dirt canal. Now, with these new canals, I do not lose a drop, the water reaches my crop from the first *dalo*. I can now store the water in my tank to ensure continuous and regular irrigation." As a result of this successful demonstration, over 1,000 farmers applied to join the scheme and 260 have already signed contracts. The method appears to be quite economic, at least for high-value crops like vegetables.

In humid and semihumid regions, supplemental irrigation is receiving increasing attention, since even where the rainfall is generally considered to be adequate throughout the year, a careful examination of rates of precipitation and evaporation often reveals that some moisture deficiency is normal during certain summer months.[2] Even

[2] An analysis of the humid southeastern United States, in which the need for supplementary irrigation is convincingly presented, can be found in C.W. Thornhwaite, An approach toward a rational classification of climate. *Geographical Review*, 1948, p. 55-94.

where moisture is normally adequate in all months of the year, brief droughts may have serious effects, as intermittent deficiencies greatly reduce crop yields.

Such supplemental irrigation has been shown to have an important bearing on yields of many crops in the southeastern United States. For instance, "Irrigation of corn jumped production an average of 25 bushels an acre in cooperative studies carried on since 1946 by scientists of ARS and the Georgia experiment station."[3] Test irrigation of seed cotton has resulted in more than tripling yields of seed cotton and two and threefold increases have been obtained in the case of tomatoes and beans and other vegetables through supplemental irrigation. Cows on irrigated pastures in Tennessee returned 43 percent more milk than on nonirrigated pastures.[4]

As a result of its proven advantages, irrigation has developed quickly in this region in recent years. The United States Census of Irrigation shows a rapid increase in the eastern United States over the last two decades in supplemental irrigation. This increase can for the greater part be attributed to advancements in sprinkler equipment, since sprinkler irrigation is especially adaptable to the supplemental character of irrigation in the humid and semihumid regions. Nevertheless, the practice has so far been adopted on only a small proportion of the farms.

Interest is gaining in supplemental irrigation in humid and semihumid countries of Europe. Here, too, sprinkler systems are dotting the landscape in increasing numbers during the summer months. With improvement in equipment and with visible evidences of the benefits of irrigation as demonstrated on a continually greater number of farms, supplemental irrigation in Europe is bound to expand.

In humid and semihumid areas, drainage is an effective tool for increasing crop production, since an excess of moisture in the soil hinders aeration and root growth. In the United States, it has been conservatively estimated that 20 to 24 million hectares have been added to the cultivable area by drainage, and food production has been at least doubled on an additional 24 to 28 million hectares

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[3], [4] Big returns from supplemental irrigation. *Agricultural Research*, March 1954, p. 14.

through improved drainage.[5] According to Jones, 20 percent of the cultivated land in the humid sections of the United States would be benefited by improved drainage, while there are some 12 to 16 million hectares of land now under cultivation on which crop yields could be increased 50 percent or more by drainage without additional seed, fertilizers, farm machinery or labor.

In general, it may be said that improved drainage has been one of the major factors in increasing crop yields in the greater part of Europe, especially northern Europe. As in the United States, extensive areas under cultivation or pasture in northwestern Europe still require improved drainage. Further east, particularly in the U.S.S.R., better drainage becomes one of the major factors in land improvement. Likewise in Japan, better drainage is of tremendous importance and the government is now devoting large expenditures toward improving the drainage of existing farmlands.[6]

Improving soil fertility

Soil fertility is, of course, basic to all agricultural production. In recent decades, much publicity has been given to soil erosion and declining fertility, particularly in the Americas, Africa and Australia. On the whole, this publicity has been justified and has directed attention to what is in many areas a serious problem. However, contrary to what is frequently believed, man has also often improved the fertility and inherent productive capacity of the land that he has used. The soils of humid forested regions are, in their virgin condition, low in nitrogen and usually acid. Thus the soils of northwestern Europe, for example, were originally of rather poor fertility, yet the use of lime to correct soil acidity, the return to the land of the manure from a dense livestock population, and the development of legume and grass rotations to add nitrogen and humus to the soil, all as part of a system of mixed animal husbandry-arable farming, have built up

[5] Lewis A. Jones, Chief, Division of Drainage and Water Control, Soil Conservation Service (Research), United States Department of Agriculture, Land drainage - An important tool to increase crop production. *Agricultural Engineering*, April 1953, p. 239-242.

[6] See Shiro Sasaki, *Land development and improvement projects in Japan*. Agricultural development series, Agriculture, Forestry and Fisheries Productivity Conference, Tokyo, Japan, May 1959.

the fertility content of the soils to a level greatly superior to that of the Middle Ages. Likewise, in much of Japan, natural soil fertility was rather low but has been greatly improved, in exactly the same way that market garden soils have often been completely transformed by use.

If the history of man's management of the soil has been one of exploitation and destruction through erosion in many places, it must be recognized that this has been due primarily to the cultivators' and even the scientists' lack of understanding of the problems of soil management under the new environment. Our present knowledge of plant nutrition, and the ready availability of fertilizers, make possible adaptations previously difficult, and in many areas permit the agriculturist to make the most of the growth potentialities of the climate. However, in other areas much research is still necessary and, particularly for the strongly leached, high rainfall soils of the tropics, much more remains to be discovered before we can make maximum use of that very favorable climatic environment. Considerable applied research is also necessary in the northern podzolic zone. There is no reason to doubt that the necessary knowledge on the nutritional requirements of these various soils can be obtained.

Poor soil fertility can therefore no longer be accepted as automatically ruling out certain areas or condemning them to uses of low productivity. For instance, superphosphate has made it possible to use more intensively deficient and unproductive soils, such as those found in many parts of Australia. In this case, the change in the nutritional characteristics of the soil is a change in kind rather than degree, since a new land-use pattern has been made possible. Addition of trace elements, where they are the limiting factor, has sometimes had quite miraculous results. Illustrating again from Australia, their use in some areas of what has been almost barren land, despite good rainfall, is multiplying the productivity of pastures many-fold. However, it may be said that this development, which will ultimately affect some millions of hectares, is as yet hardly beyond the pilot stage. No doubt in the future fairly easy remedies will be found for other areas of inexplicably unproductive soil in various parts of the world.

Soil fertility may be maintained and built up by the use of legumes and grasses as a part of the crop rotation, in order to add nitrogen and humus; by returning to the soil, in the form of farmyard manure and composts and even human excreta (night soil), as much as pos-

sible of the nutrients removed by crops; by the addition of inorganic or chemical fertilizers containing specific elements; and by lime and other amendments. Consideration of the extent to which these various practices are followed, or rather more often not followed, in various parts of the world, is sufficient indication that the potentialities for increasing production through better soil management are tremendous.

The use of legumes and grasses to add nitrogen and humus to the soil has been characteristic of the moister parts of the temperate regions, but the development of grasses and legumes adapted to the more difficult climatic regions, and suited to grazing and to green manuring requirements, will be of great assistance in improving the fertility levels of the northern podzolic soils and the tropical latosols, both groups being deficient in nitrogen and organic matter. For instance, growing leguminous shrubs on the bunds to provide green manure for rice fields in Madras has proved fairly successful, and a similar method of raising production by increasing the nitrogen levels of paddy fields should be practicable for much of southeast Asia. In Australia, as mentioned in the section on extending areas under cultivation, leguminous pastures, along with trace elements where necessary, can be used to build up the productivity of large areas of land of low fertility, which have hitherto contributed very little. The same is true of many other areas in the more recently settled continents and in Africa. Again, a great extension of the use of grasses and legumes as part of the crop rotation in the more humid parts of the extensive monocultural cereal belts of the world (United States, Canada, Australia, Argentina and the U.S.S.R.) would generally raise yields. In the drier areas, where forage crop yields are low, the problem is more difficult. In general, it may be said that outside northwestern Europe and limited areas elsewhere, the development of good rotations, which is so important in soil fertility, has not progressed far. In time, it may be expected to transform the agricultural pattern over extensive areas in many parts of the world.

Farmyard manures and composts have been of the utmost importance in maintaining soil fertility at a fairly high level in northwestern Europe and east-central Asia. In other parts of the world, covering by far the bigger part of the area, manures are mainly wasted or only very partially utilized, at least for agricultural purposes, while other forms of refuse and sources of organic matter are little used. Short-

FIGURE 13. – In many parts of the world natural manure is used as fuel. Above photo shows cakes of dung being sun-dried for this purpose in Turkey.

ages of fuel, labor and transport costs, and sanitary reasons, are partly responsible for this and, in some places, the burning of dung is unavoidable until alternative sources of fuel are made available. However, ignorance and apathy bear a much larger share of the responsibility. Particularly great are the possibilities from use of organic waste materials in Asia and the Far East, where the dense human and often dense animal populations produce immense quantities of excreta and other litter, where labor costs are low, and distances over which the materials need to be transported generally short.

However, these materials are only very partially and inadequately used outside northeastern Asia. In India, where an estimated 40 percent of the animal excreta is burned for cooking and heating because wood is so scarce, and also in some other countries, provision of an alternative form of fuel will be an important means of raising food production. The concept of balanced land use is again very relevant in this context, since only a proper balance between forests and agricultural lands can meet the enormous needs of the vast rural populations of the underdeveloped countries for cooking and heating materials. In urban areas, coal, oil and other derivatives can supply these needs, but in rural areas fuelwood will be for long the practical alternative to the waste of precious nutrients through the burning of manure. Growing of trees can usually be incorporated into the land use without detriment to the agricultural area, even in densely populated parts, since many opportunities exist for planting trees in land not suitable or otherwise unavailable for cultivation. These trees also have a generally beneficial effect on crops, through protection against winds and soil erosion and possibly through slight amelioration of the climate in some instances.

Also very important is the conservation, by proper handling, of the nutrients in the excreta which are used for agriculture. Studies have shown that in India about three quarters of the nitrogen and the potash in the animal excreta used for manure are lost, compared with a loss of about half under better handling. Despite the fact that composting has been extensively developed for hundreds of years in the civilizations of China, Japan and Korea, its potentialities as a means of conserving and using organic wastes have been largely neglected in other parts of the region. During the last 15 years, India has been making an attempt to remedy this deficiency through the town

and village compost schemes but the production is still small compared with the potential.

The failure to use human excreta for some productive purpose is one of the most notable examples of waste in the world. In east-central Asia, as is well known, human excreta are used under the name of night soil as fertilizer. In China, about 200 million tons of night soil are estimated to be available each year.[7] However, a great deal of education and considerable investment is needed to provide for its maturation before use in order to destroy the pathogenic bacteria carried by the raw night soil. In Japan, the night soil is deposited in maturation tanks for about one month. The sanitary use of human excreta has in the past probably been generally uneconomic under western conditions, though a few cities in Europe and America have established facilities for preparation of sludge and its sale to farmers. Recent scientific work may eventually open up a new and promising avenue of use. This work has shown that algae can grow prolifically in decomposing sewage, and that it is theoretically possible to convert practically all of the nitrogen and a large part of the phosphorus and potash into algal cells, rich in protein. This work is still, however, at a research stage, which is a long way from practical application, because of difficulties in controlling the process. It does, nevertheless, open up the possibility of conversion of sewage from an expensive and wasteful liability into a profitable and valuable source of protein, very suitable for livestock feeds. From an economic point of view, municipal authorities would hardly be able to afford not to take advantage of such an opportunity. Considering the fact that feed, and partic-

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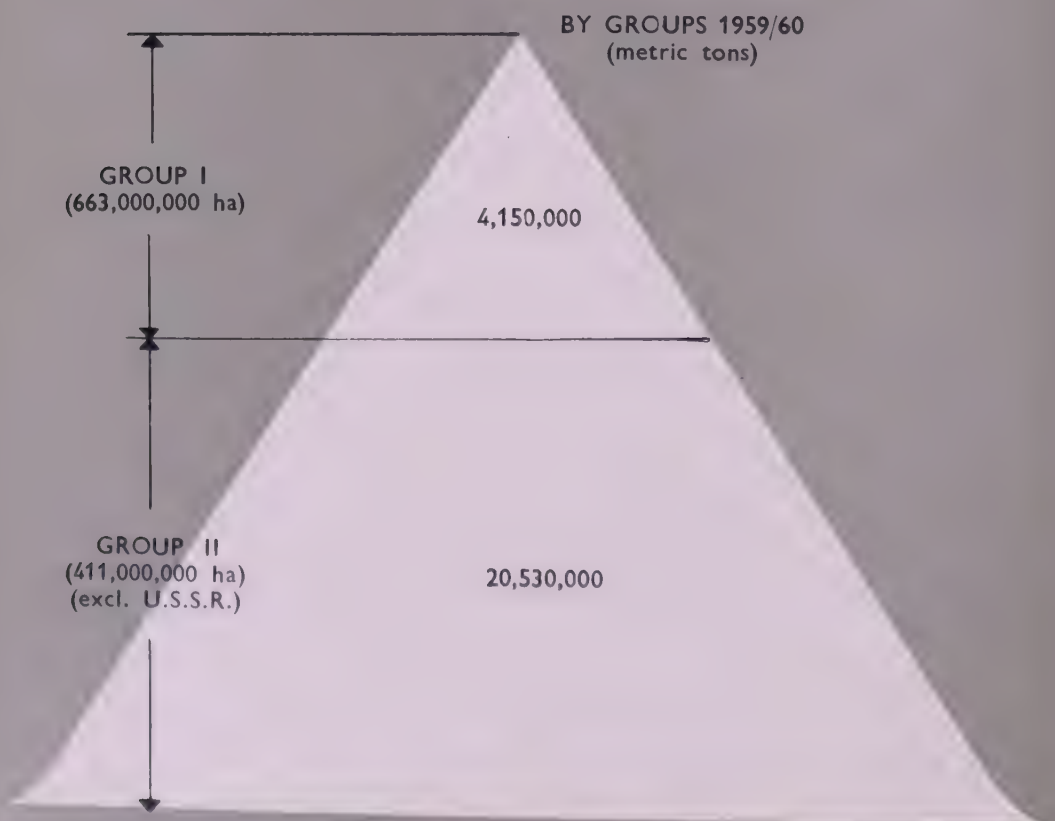
[7] The following excerpt from the *Report of the Indian Delegation to China on Agricultural Planning and Techniques* (1956), gives interesting information on China: "About 85 percent of the total cultivated area in China is manured, through organic manures such as night soil, stable manure, compost, green manure crops, mud from the bottom of canals and ponds rich in organic matter, oil cakes, etc., and through chemical fertilizers. It is estimated that some 50 percent of the manure used is night soil and stable manure, 20 to 30 percent compost and 10 to 15 percent green manure. The use of chemical fertilizers is relatively small but it is steadily on the increase. As against 1.2 lakh tons in 1949, it has risen to a figure of 10.3 lakh tons in 1955. The target for 1956 is 17.3 lakh tons. Every effort is being made to utilize night soil and stable manure."

Chart 8. - CONSUMPTION OF FERTILIZERS PER HECTARE OF ARABLE LAND

BY GROUPS 1959/60

Total consumption of fertilizers



— or tons — of extra rice. The average response to phosphatic fertilizer was rather less, because some Indian rice soils do not need phosphate at present. Even so, the average response to 33 kilograms of P_2O_5 per hectare was 245 kilograms of rough rice. Thus the combined increase in yield obtained from applying 33 kilograms of nitrogen and 33 kilograms of phosphate (where needed) per hectare was not less than 660 kilograms per hectare. This is an increase of more than 50 percent, as the average yield of rice in India is 1,275 kilograms per hectare.

Heavier dressings of fertilizers used with improved varieties of rice secure even greater yield increases, and other improvements in methods of farming, which the cultivators will gradually learn to adopt, will raise yields still higher. From experiments in India and elsewhere, it has been estimated that the average rice yield in India could be doubled by the combined application of fertilizers (at 33 kilograms of plant food per hectare), new varieties, better methods of growing the crop, and the control of pests and diseases. Raising the level of nitrogen application to 90 kilograms per hectare — the average rate used in Japan — which could safely be done with suitable new varieties, would further raise the Indian yield of rice to an average of nearly two and a half times the present level, or about 3,025 kilograms per hectare.

Irrigated wheat in India has given comparable findings, and so have the numerous trials carried out on rice and other crops on farmers' fields in other countries of southern Asia and the Far East. Similarly, outstanding results have been obtained in Mexico on irrigated wheat by heavy fertilizer applications and the use of new varieties resistant to lodging and disease. In fact, average wheat yields in Mexico have almost doubled since the war, rising from 820 kilograms per hectare in 1946 to 1,420 kilograms in 1960, etc. Some farmers are even harvesting 3,000 to 4,000 kilograms of wheat per hectare on land that yielded 400 to 700 kilograms per hectare only four years earlier. The farmers were encouraged to adopt the new methods by widespread trials on ordinary fields.

Yet more examples of increases in the yields of cereals, achieved by using fertilizers on ordinary cultivators' fields, could be quoted from West Africa and other parts of the world. And cereals are not the only food crops to benefit in this way. Root or tuber crops, which are the main sources of food in many parts of the humid tropics, also respond well to manuring. These crops generally require complete

fertilizers, including potash as well as the nitrogen and phosphate which are so widely effective with cereals. In Ghana, complete NPK fertilizers at quite low rates of application (around 33 kilograms per hectare of each nutrient) with yams and cassava gave yield increases averaging 50 percent, and there is no doubt that, with heavier fertilizer applications and other improved methods, the yields could have been doubled.

Experience in Japan may also be used to illustrate something of the potential increase in production from the use of nitrogen. In this country, an average of about 100 kilograms of nitrogen is used per hectare of rice, of which about two thirds come from manufactured inorganic sources. It is estimated that the return of polished rice is at the rate of about 10 kilograms for each kilogram of nitrogen applied, so that it can be suggested that the inorganic nitrogen alone produces an increase of about 600 kilograms of rice on each hectare sown, or about 1.7 million tons per year. The potentials from the effective use of nitrogen alone in monsoon Asia are tremendous. In India, over a million tons of nitrogen would be needed to give only the rice crop the moderate dressing of about 30 kilograms of nitrogen per hectare which experiments suggest would produce an increase of more than 10 million tons of polished rice per year. Speyer forecast about seven years ago that by the year 2000 the consumption of nitrogen in commercial fertilizers would have increased to 50 million metric tons from its then level of about 6 million tons. Consumption has since risen to 11 million tons. If an appreciable portion of this 50 million tons is used on cereals, and if the ratio of return for all cereals is approximately what it is for wheat at Rothamsted, the world's grain supply will be increased by some hundreds of million tons by this one means.

Phosphate, potash and lime will also play their roles in increasing the production value of each unit area of land. The analysis made by Yeats and Boyd for the United Kingdom indicates that even many advanced countries are far from a satisfactory use level with regard to potash and lime, if the British data are accepted as being reasonably applicable to other similar areas.

Even in Europe, fertilizer usage is extremely uneven and large potentialities exist for increasing production through greater application, while remaining within economic limits. The high levels of

fertilizer nutrients applied to the soil in the Netherlands are very much greater than in most other countries, although it is generally accepted that much wider usage is preferable in most other countries. For instance, before the war, the Netherlands was using ten times as much nitrogen, five times as much phosphoric acid, and ten times as much potash per hectare of arable land as the United Kingdom.[9] Since then, the difference has become somewhat less but remains very high. "In Sweden it has been estimated that even twice the consumption of artificial fertilizers... will still be economical because of considerable increases in the yield."[10] In fact, there has been a real breakthrough in raising the yields of cereals in western Europe since the war, and the average yields per hectare have reached levels that formerly would have seemed impossible, as a result of using heavy fertilizer applications — particularly nitrogen — on new stiff-strawed varieties.

An extremely interesting correlation between crop yields and input of fertilizers is indicated by the scatter diagram in Chart 9 with its line of best fit and the range of one standard error of estimate above and below the curve (area shaded gray).

It does not follow, of course, that it is necessary only to add a given quantity of fertilizer to obtain a given yield. Countries with a high input of fertilizers have paid attention to other factors, such as irrigation, varietal improvement and disease control, all taught through a well-organized extension system which can build in turn on a good system of universal education. Japan, for instance, has practically the whole arable area under irrigation. Unless irrigation or a humid climate during the growing season provide an adequate and assured supply of moisture, there is a limit to which fertilizers can be applied without burning the crop. Nevertheless, the chart does indicate that the supply of nutrients is a necessary condition for high yields and that up to quite a high level, the greater the quantity of nutrients that can be added, the higher will be the yield.

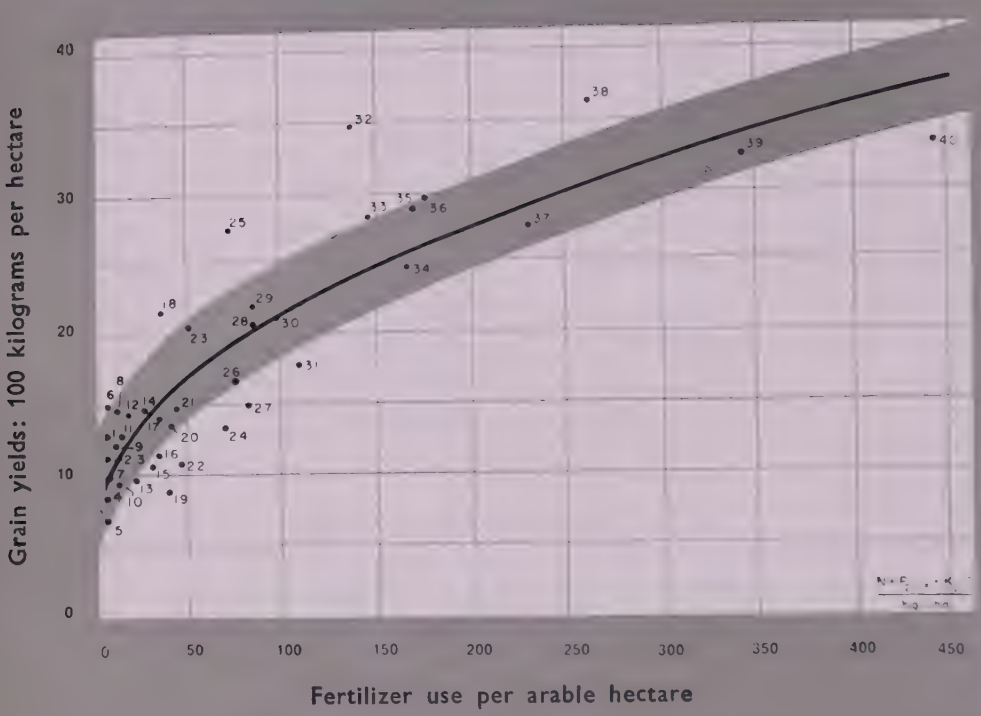
One of the biggest future potentialities lies in the use of fertilizers on pastures, which has only recently come to be widely recognized as good practice. This is, of course, furthest advanced in northwestern

[9] A.M. Smith, *Manures and fertilizers.* London, Nelson, 1952, p. 215.

[10] *Proceedings of the United Nations Scientific Conference on the Conservation and Utilization of Resources, 1949*, Vol. 6, p. 299.

Chart 9. - USE OF FERTILIZERS AND YIELD OF GRAINS

(Per hectare, 40 countries, 1956-58)



1. ARGENTINA
2. PAKISTAN
3. TURKEY
4. INDIA
5. SYRIA
6. INDONESIA
7. PHILIPPINES
8. CANADA
9. COLOMBIA
10. MEXICO
11. BRAZIL
12. CHILE
13. SOUTH AFRICA
14. YUGOSLAVIA
15. EL SALVADOR
16. SPAIN
17. GREECE
18. UNITED STATES
19. PORTUGAL
20. CEYLON
21. POLAND
22. AUSTRALIA
23. ITALY
24. PERU
25. UNITED ARAB REP.
26. FINLAND
27. ISRAEL
28. SWEDEN
29. FRANCE
30. AUSTRIA
31. REPUBLIC OF KOREA
32. DENMARK
33. UNITED KINGDOM
34. NORWAY
35. TAIWAN
36. SWITZERLAND
37. GERMANY, FED. REP.
38. JAPAN
39. BELGIUM-LUXEMBOURG
40. NETHERLANDS

Europe and in the opposite quarter of the globe in New Zealand, where similar climatic conditions exist. However, in both cases there are strong possibilities for increasing production. An example of the possibilities for greater production in northwestern Europe may again be taken from the United Kingdom, where according to Smith, "The productivity of grassland is in general at a very low level on account of the limited use of fertilizers."[11] Although the benefits of application of nitrogen to grass have been fully demonstrated, only about half the area under grass, which provides more than half the total feed units grown for livestock, receives nitrogen, and there are approximately 400,000 hectares of untreated grass, according to Smith, which could give a

[11] A.M. Smith, *Op. cit.*

possible yield of 6 quintals of extra hay from the use of quite moderate amounts. Apart from the question of quantity, the protein content of the hay could be increased 30 to 40 percent by applying 33 to 45 kilograms of nitrogen some 10 to 20 days before cutting (Smith).

In New Zealand, some 2 million hectares of a total of 12 million hectares of pasture are top-dressed with superphosphate and/or lime. In Australia, the use of superphosphates on pastures has increased rapidly in recent years but, as an Australian agricultural economist noted in 1953, the acreage involved " is not only an exceedingly small proportion of our grazing lands where rainfall is adequate for pasture improvement, it is also a mere fraction of the country where other physical features — topography, ground cover, soil type and so on — are also favourable for pasture development. "[12] During the last decade, there has been substantial expansion in the area of pasture fertilized.

It would, of course, require an enormous amount of detailed work, even if sufficient experimental results were available, to estimate with any degree of accuracy the potential contribution which better soil fertility practices could make to agricultural production. It would, however, be a conservative estimate that with the exception of a very few countries, such as Japan and the Netherlands, production could be increased by at least 50 percent, and in many parts of the world could be doubled, simply through the better and more intensive use of fertilizers, manures and legumes. Lack of information, lack of capital, and lack of adequate distribution and transport facilities are the main problems preventing the cultivator from obtaining such increases.

Plant breeding and seed improvement

It is the purpose of plant breeding to make available for farmers seed with better varietal characteristics for their particular conditions than those which they are already using. As a plant breeder has expressed it, " What comes out of the soil is dependent on the inherent potentiality of the seed that we put into the soil. No matter how good the cropping system may be, no matter how heavy the fertilizer

[12] P.A. Reid, Pasture improvement. *Quarterly Review of Agricultural Economics*, April 1953, p. 63-68.

dressings that are applied, the crop that is obtained is dependent on the yielding ability of the particular variety that is employed. At all levels of soil fertility the varietal characteristics of the seed used are limiting factors in the yield that is obtained and in the quality of the produce."[13]

The improved varieties made available by the plant breeder may yield more per unit because of either or both of two reasons: (*i*) the improved variety may have a higher biological capacity to produce, provided it receives the necessary nutriment and other conditions are favorable; or (*ii*) the new variety is more resistant to certain plant diseases and pests, or to extremes of weather, such as aridity or cold, than previous varieties. Plant breeding may, therefore, be one of the main means of minimizing the effects of plant diseases and pests or combating unfavorable natural conditions.

Both selection, which involves choosing the best of what already exists, and hybridization, which involves the creation of new genetic combinations, offer tremendous opportunities for further increasing agricultural production in the world, just as they have made a major contribution to raising production in the past. For instance, in Sweden, where the indigenous unbred varieties of cereals, which were used before plant breeding began in the 1880s, have been preserved, tests show that plant breeding alone has contributed a 30 percent increase in yields in the case of winter wheat and 12 to 15 percent in the case of other cereals.[14] In the agriculturally more advanced countries, where plant populations have already been well worked over, further advances will probably come mainly from hybridization. On the other hand, in underdeveloped countries, hundreds of varieties of the basic food crops, some good, some bad, some indifferent, are in use by farmers, and even though a large measure of selection and upgrading has been carried out by the farmers themselves over the centuries, the scope for improvement by systematic collection, testing, purification and concentration on a limited number of varieties, each of which is more suitable to a particular set of conditions, is usually substantial. Beyond this

[13] Unpublished paper read by Dr. R.A. Silow before an FAO Agriculture Division staff meeting.

[14] A. Äkerman, The improvement of the yields of cereals in Sweden due to plant breeding. *Proceedings of the United Nations Scientific Conference on the Conservation and Utilization of Resources, 1949*, Vol. 6, p. 297-301.

task of selection, the production of new varieties, specially bred for resistance to specific hazards or for high yield potentials, opens up great possibilities which have only been very partially explored in most underdeveloped countries.

Very substantial increases in production could be obtained, especially in the less developed regions, merely through the wider use of known improved varieties in areas for which they are suited, substituting them for those traditionally grown by farmers. These varieties are often little used, because farmers are not aware of them, or they are not convinced of their superior merits, or the seed may be hard to obtain, or new varieties may be more demanding, e.g., of fertilizers which may not be available. Too commonly research has been treated as an end in itself, without paying comparable attention to facilities for multiplication and distribution of the seed of the newly obtained varieties or to education and extension.

Unfortunately, little of the information that would be needed for a careful assessment of the scope for increasing yields through new varieties has ever been brought together in one place. Even information on what might be achieved by effective use of existing proved varieties is lacking on any over-all basis. Still less is any survey possible in quantitative terms of the potentialities through new selection or hybridization, since even apart from lack of information, the degree of success of efforts cannot be predicted. One can, however, cite a few examples of some of the possibilities.

One of the most obvious opportunities for increased production through plant breeding is given by hybrid maize. In the United States, present-day hybrids yield 40 to 45 percent more than nonhybrid varieties. Their general introduction and the ability of these varieties to utilize heavy applications of nitrogen fertilizer have been the most important factors in raising maize production in the United States from 53 million tons before the war (1934-38) to 111 million tons in 1959/60, on a sown area 13 percent smaller. In many of the other maize-producing countries, little of this potential has been garnered, although in many countries, particularly in Europe and Latin America, a great deal of work has been done on breeding hybrids suited to local conditions. For instance, in the more important maize-producing countries in Europe and the Near East, which are working co-operatively under FAO auspices for the introduction of hybrid maize, some

45 percent of the total maize area was sown to hybrids in 1961, compared with 6 percent in 1953. The use of hybrid or improved varieties on the 50 million hectares of maize in the world (excluding the United States) could mean an extra production, from the effects of better varieties only, of 20 to 30 million tons of grain in Africa, Asia and Latin America, where maize is often an important element in the diet, and in Europe.

A good example of the prospects from using superior varieties, accompanied of course by an appropriate improvement in plant nutrition, is obtainable from Yugoslavia, where in 1957 a team of four FAO experts introduced some higher-yielding wheat varieties from Italy which proved to be well adapted to conditions in Yugoslavia. By 1959, 15 percent of the wheat area in Yugoslavia was sown to these varieties, while use of fertilizers on wheat had risen to 104 kilograms per hectare from 34 in 1949. Yields of all wheat rose from 12 quintals to the hectare over the period 1949-52 to 17 quintals for the 1959-61 average. At the same time, consumption of fertilizer per hectare was increased from 34 to 106 kilograms.[15]

Great opportunities also exist through improvement of rice varieties, since among the major rice-growing countries of the Far East only Japan has made a systematic and comprehensive attempt over a sufficiently long time to improve the varieties grown by farmers. Here, by intensive breeding over three quarters of a century, improved varieties have been produced suitable for every part of the country, and at the same time full facilities for the multiplication, certification and distribution of seed have been established and farmers educated in the value of using these varieties, along with other improved cultural methods. As a result, more than 70 percent of the rice area is under improved varieties. While the latter are by no means the only element in the high yields obtained in Japan, which are nearly three times the regional average, the high yields could certainly never have been obtained without the production of these varieties, which are able to respond to the large quantities of fertilizer used and to other practices.

In Taiwan and Korea, rice-breeding work also dates back several decades, originally as a result of Japanese rule, and much progress

[15] FAO. *Possibilities of improving food production, marketing and consumption*, p. 40. (Document FFHC/TE-EC/2)

has continued since the war, with the result that Taiwan now has 60 percent of the area under improved varieties, and South Korea 33 percent. Mainland China also reports very rapid progress during the last decade. Since the war, many countries have undertaken breeding programs on a large scale but the proportion of the area actually planted to improved varieties still remains small, probably nowhere exceeding 10 to 15 percent.

There is every reason to believe that plant breeding and improved cultural practices can give big increases in yields on the other tens of millions of hectares of rice in the Far East. Despite the increasing attention given in the Far East both to rice breeding and to getting the improved varieties into use, in most countries suitable varieties are available for only part of the area and these are usually employed only by a small proportion of the farmers who should be using them. There is also little doubt that with further work and experience of the use of new varieties by farmers, varieties can be produced which will outyield those that research workers have made available so far. A few examples, taken very much at random, might be mentioned of possibilities promised by varieties already proved or under test. In Ceylon, for instance, four new varieties, that in trials have given yields ranging from 13 to 37 percent over the previously recommended varieties for the same areas, have recently been made available. In Uttar Pradesh in India, a rice of Chinese origin has given trial yields of 25 to 50 percent more than cultivators' varieties. A large number of improved varieties available in East Pakistan, mostly from research work done before the war but scarcely in use at all, are considered capable on the average of giving yields about 25 percent above those at present being used. In a similar situation in Burma, some 60 improved varieties under only limited distribution are considered capable of giving yields of 10 to 15 percent above cultivators' unselected varieties. In the Federation of Malaya, postwar work has led to selection of a variety for one area which is expected to yield about 30 percent more than those now in use. As for the future, the nations of monsoon Asia have been co-operating for over ten years, under the leadership of FAO, in a project to cross the japonica and indica types of rice, with the aim of combining the qualities of responsiveness to fertilizers and high potential yield of the former with the adaptability of the latter to the environmental conditions of subtropical Asia.

Many promising lines have been obtained and are still on trial. This project, which like all breeding projects will require many years to begin to give results, may ultimately prove of the utmost importance for raising rice yields in southern Asia.

In the United Arab Republic, the work of an FAO expert over the period 1953-58 has been exceptionally successful, even though rice yields were already high. By bringing in outstanding varieties from other parts of the world, at the same time as cultivation and fertilizer practices were improved, the yield per hectare has been increased from 3.67 tons prewar to 5.2 tons in 1957-59 (41 percent), and on an increased area, so that total rice production expanded from 650,000 tons to 1,400,000 tons in 1957-59.

Similar opportunities exist in respect of wheat and barley in some countries in the Near East region, where little varietal improvement has so far taken place. Here FAO has initiated a regional co-operative improvement project, through disease resistance nurseries, co-operative yield trials and introduction of breeding parents from other regions, giving first priority to disease resistance and high yields.

Generally, very little has been done to select and improve the indigenous varieties of sorghums and millets which provide a substantial part of the food supply in many areas of Africa and Asia. Partly as a result of this lack of varietal improvement, sorghum and millet yields are extremely low in those areas.

There is every reason to believe that selection and breeding could do at least as much to raise yields and improve the quality of the food crops other than cereals (such as the various roots, pulses, fruits and vegetables) of the peoples of the underdeveloped regions. In fact, it may well be that the scope for plant improvement is greater in these cases, since less attention has been paid to the improvement of the noncereal food crops. Little attention has been given in most countries to the breeding and selection of herbage and fodder plants, where there is great scope for increased yields. On the other hand, the scope for rapid varietal improvement in industrial and other export crops is generally less, since these have more often been produced on estates, where attention has already been given to breeding.

One of the most dramatic consequences of plant breeding is that it may open up entirely new geographical areas by producing plants with greater resistance to the limiting environmental factor. Thus Marquis

wheat, developed from a cross between a European and an Indian variety, opened up most of western Canada for cereal production as a result of its outstanding earliness and yield. Breeding for resistance to drought has greatly extended the limits of the wheat belt in Australia and North America. At present, a great deal of attention is being given in various countries, particularly in the U.S.S.R., to pushing the frontiers of various crops northward through breeding earlier-maturing varieties, and this will be one of the most important factors in the successful utilization of the northern podzolic zone.

Better equipment

For too many people agricultural progress is summed up in one word — tractors. From the point of view of economic progress, this emphasis, even if one-sided, is not altogether mistaken, though the specific attempts to introduce powered machinery into backward agricultural economies are often entirely ill-conceived. By making it possible for each man to cultivate and harvest more land or look after more animals, mechanization is a vital element in raising the productivity of labor and therefore in economic progress. Where labor is scarce in relation to the land available, or where industrial development and higher wages in the cities are taking labor away from the land, mechanization is essential to maintain production.

However, for the purposes of this study, it is necessary to assign a much more modest place to mechanization, since the chief function of machinery is to make it possible for each man to do more work, not to make each hectare grow more food. Nevertheless, improvements in equipment, including animal-drawn implements and hand tools, as well as tractors and tractor-drawn machinery, can make a very appreciable contribution to raising crop yields per hectare, firstly, by enabling various operations to be performed better, and secondly, by making possible more timely operations. Such improvements may also make it possible to farm land that could not be farmed at all with more primitive implements.

In many parts of the world, the implements available to farmers for working the soil are not adequate for the preparation of a good seedbed or properly to destroy weeds. The mere substitution of these by stronger or better-designed hand tools or animal-drawn implements could make an appreciable difference to yields. The substi-

tution of the hoe for the planting stick, or, at a higher level, putting a steel point on the share of a wooden plow, results in better cultivation as well as easier work. In still more advanced economies, improvements in plow design, facilitating conservation of moisture or drainage, as may be required, may enhance yields. Improvement in equipment may also reduce losses during harvesting.

The element of timeliness is, of course, a most important factor so far as crop yields are concerned. For instance, in many places it is not possible to begin to prepare the ground until the rains come, and thereafter, the time which elapses before the crop must be sown, if it is to do its best, may be very short, so that time does not permit of adequate preparation; or if rains are delayed, the crop may have to be sown too late, thus reducing yields. Better animal-drawn equipment or powered machinery which make it possible to work the ground more quickly, or perhaps to commence preparation in advance of the rains, so that sowing can always occur at the optimum time, may make a substantial difference to yields in some years. Improved implements and sources of power, combined with plant breeding to control harvesting times, can sometimes make it possible to fit an additional crop into the annual rotation.[16] Ability to eliminate weeds in fallow without delay may make a substantial difference to the yield of the next crop. Where harvesting must be carried out over a short period between the time when the crop is ripe and a rainy period arrives, losses may sometimes be quite heavy. The advent of machinery which makes it possible to take the harvest off more quickly can avoid these losses. Thus every mechanical improvement which makes it possible for a farmer to do his plowing, harvesting, etc., more quickly, gives him greater control over the elements.

There is no doubt that mechanization has been a factor in improving average yields in the economically advanced countries, probably principally by enabling a greater proportion of the crop to be sown or harvested at the best time or by timely eradication of weeds. Thus by increasingly substituting tractors for horses, the farmers of western Canada have been able to complete their spring sowing in time to cultivate their fallow before excessive weed growth during

[16] See Chapter VI of *The appraisal of agricultural, fishery and forestry resources in relation to needs in the Lower Ganges-Brahmaputra basin*. Rome, FAO, 1959.

the early summer, something which was not possible when using a horse team. This has probably had a substantial effect in raising average yields since the war. In the more backward economies, improvement in the timing of operations and in their effectiveness opens up even greater opportunities for increasing production.

In the past 15 years, special methods and machines have been developed which permit economical crop production in semiarid regions where, owing to low rainfall, profitable and productive farming had been thought impossible.

The development of dry-land farming, as the method is called, is particularly important in world agriculture, because an important part of the lesser developed agricultural areas is to be found in regions of extremely low rainfall, a factor which in the past had made agricultural development impossible without irrigation. This has hampered progress, because only a fraction of these semiarid areas can ever be economically developed by irrigation — and many can never be developed due to lack of water resources.

Good examples of dry-land farming technique are to be found in the southwestern Great Plains region of the United States and in the drier areas of Australia. While crop production may still be severely limited by drought and, in some years, yields are only sufficient to keep farmers solvent, total crop failure in these regions is practically a thing of the past.

An essential in dry-land farming is to have specialized hand- and animal-operated and power-driven machines to till and seed the land in the proper manner and, particularly, to carry out these operations quickly, so that a crop can be planted at the most desirable time.

An example which holds promise for many similar areas may be given from Libya, a typical dry-land farming country in North Africa where primitive wooden nail plows have been used since biblical times to till the land. The government, in its efforts to improve the rural economy and the standard of living of the farming population, realized that only through the introduction of modern methods and tools would this aim be achieved. The government therefore requested FAO to provide the services of a specialist in this field under its technical assistance program.

An engineer was appointed by FAO in 1955 to carry out a survey of tools in use on the farms. He found a considerable variety of

wooden plows, digging hoes, and some smaller equipment, but scythes were unknown and such equipment as motor pumps, carts and steel plows were to be found only on the most modern farms of the coastal belt.

After this survey, the expert drew up a list of tools which he believed should be introduced to improve tillage, seeding and harvesting practices, and sufficient of these for demonstration purposes were purchased by the Government of Libya. The tools were loaned out free of charge to co-operating farmers. Group demonstrations as well as individual farm visits were arranged to train the farmers in the use and care of the tools. The program aroused considerable interest and support in the farming population.

Recently, an animal-drawn plow and cultivator particularly suited for dry farming under local conditions has been designed and arrangements made with local manufacturers to produce the most useful and popular types of equipment on the spot and at cheaper prices.

Since the introduction of this program, considerable progress has been made in increasing the production per unit of cultivated land. This educational and training campaign is still continuing with great success.

The results in Libya provide an example of what can be done in vast areas of the world, particularly in North Africa and the Near East, where water is very scarce. Dry-land farming, if properly introduced, organized and operated, can greatly increase the production of cereal and forage crops in these regions.

Improving crop rotations

The value of legumes, and particularly leguminous pastures, as a first stage in bringing under cultivation new lands that have been passed over because of low fertility, has already been emphasized in the present report. The introduction of legumes in areas where the traditional crop rotation has been varying combinations of cereals and fallow, can also play an important part in raising crop yields, diversifying production and improving nutrition.

The predominant rotation in many parts of the Mediterranean is wheat/cereal/fallow (for grazing), which in some cases has deteriorated into the monocultural rotation of wheat/wheat/cereal. Thus the worst possible conditions have been created for the accumulation of moisture

and organic matter in the soil and the provision of fodder for grazing animals.

Trials in Mediterranean countries, particularly Greece, have shown that yields of wheat and other cereals can be doubled by the inclusion of fertilized annual legumes in the place of the fallow, such as *Vicia faba*, *Pisum sativum*, *Lens esculenta*, *Lathyrus cicera* and *Cicer arietinum*. In Greece, for example, the yield of wheat has been raised from 900 to 1,600 kilograms per hectare by the inclusion of annual legumes and to 1,800 to 2,000 kilograms per hectare when these were fertilized by phosphorus (180 to 350 kilograms per hectare). Application of these practices has made it possible to increase average wheat production in the plains by 20 to 30 percent, solely through an increase in yield approaching 100 percent in some cases. In addition, the growing of these legume crops provides an important supply of protein for both humans and livestock.

This practice may have wide application in other parts of the Mediterranean where wheat yields are very low, such as the United Arab Republic (910 kilograms per hectare), Tunisia (380 kilograms per hectare), Tripolitania (370 kilograms per hectare), Morocco (470 kilograms per hectare), Algeria (710 kilograms per hectare) and Turkey (1,160 kilograms per hectare). The inclusion of legumes, particularly grain legumes, in cereal rotations could be used — apart from its favorable effect on soil fertility — to provide a more balanced diet.

An example of the successful introduction of a grain legume in African farming is the cultivation of groundnuts in association with millet in Senegal. Here the area under groundnuts exceeds that under millets by some 10 percent. This has led to an improvement in the nutrition of the farming population and livestock, as well as supplying a valuable cash crop for the local export market. In Asia and the Far East, the staple diet of the population is rice and there is here a great need to supplement this diet with vegetable proteins. If, where additional irrigation water is available, grain legumes were grown in rotation with rice crops, the diet would be greatly improved.

Reducing losses due to diseases and pests in growing crops

Before modern methods for plant protection were developed, widespread famine caused by locust plagues and other destructive pests and diseases has been frequently recorded in history. The oft-

cited examples include the potato blight disease, which was mainly responsible for the great famine in Ireland during the forties of the last century, and the grapevine phylloxera pest, which is said to have caused more economic damage to France than the disastrous war of 1871 and the subsequent indemnity. Ceylon was one of the world's greatest coffee-producing countries until rust disease became prevalent, as a result of which exports of coffee declined between 1879 and 1893 to less than 7 percent of the former shipments. Extremely large quantities of food and industrial crops are still destroyed each year by diseases and pests which attack either the growing crop or the product after it has been harvested. We are a long way from being able to make a blanket estimate of the extent of such losses but they are certainly equivalent to the produce of many hundreds of millions of hectares. Most of these losses could be prevented by the full application of present knowledge regarding methods of prevention and control at a cost usually very small in relation to the value of the additional produce. For the world as a whole, the gap between knowledge and practice is probably greater than ever before, owing to particularly rapid scientific progress in recent years. However, this accelerating rate of discovery gives promise that economic means will be found to overcome many of those ravages which still escape the research worker.

Man bestows the name of pest, which for purposes of brevity may be taken to cover all forms of attack upon growing and stored crops, upon those forms of life which compete with him for the use of the crops and products upon which he depends for food and clothing, or which otherwise interfere with his comfort. They include insects and mites, fungi and bacteria, viruses, the higher animals, such as rodents, rabbits and birds, and finally weeds. All of these reduce crop yields, sometimes even completely destroy crops, either by living upon them or competing with them for their source of nutriment, or else they cause loss of immense quantities of food in the field or after harvesting and before it reaches the consumer. Increased acreage, higher yields and better conservation and use of the harvested product are alternative methods of increasing the effective food supply.

The competition between mankind and these enemies is an unceasing one, in which the struggle sways now to the advantage of one side, now to the other. The concentrated production of a single crop over

a large area provides excellent conditions for the development of pests and diseases and the more intensive production becomes, the more favorable do conditions become for them. Since man in his agricultural progress is largely responsible for providing the food which pests and diseases must have if they are to live and grow, progress in control techniques is necessary merely to break even; and frequently when methods of controlling a particular pest are found, a new resistant strain develops.

The past 15 years have seen remarkable progress in chemical methods of control of pests and diseases of growing crops. Many of the new synthetic chemicals such as DDT and BHC were developed during the second world war and became available to farmers only from 1946 onward. These and a few others have made possible big increases in yields for some crops in those countries where they are being generally used. For instance, DDT has been largely responsible for an increase of over 100 percent in the yield of potatoes in the United States. Remarkable increases have occurred in the yield of a number of other vegetables and fruit trees since the advent of such chemicals.

The new, more effective chemicals, and for that matter the older ones, are little used outside North America, western Europe and a few other countries, and there is therefore a tremendous backlog of existing knowledge which could be drawn upon to reduce losses from pests and diseases. Generally speaking, whereas several hundred or even thousands of tons of pesticides are used in the more advanced countries, their use in the majority of countries is quite negligible. In the more advanced countries, too, many farmers are not taking advantage of the possibilities which these afford for increasing their crop yields.

A few estimates have been made of the extent of the losses due to the depredations of diseases and pests against growing crops and pastures. The "fact book" prepared by the Committee on the Centennial of Professional Entomology in the United States specifies: "It has been estimated that the proper use of pesticides can add an equivalent of 40 million hectares or an additional one-third increase in total production of all farm products within the next 50 years. It seems reasonable to assume that as more insecticides and other farm chemicals are adopted for the control of pests, from 30 to 50 percent

additional yield per acre is feasible on many major crops." Despite the relatively advanced application in the United States of knowledge in the fields of entomology and plant pathology, annual losses from insects, including livestock losses, are estimated at $4,000 million and those from plant diseases at $3,000 million. In the United Kingdom, crop losses in 1947 have been estimated as equivalent to the produce of 33,000 farms out of half a million.[17] In France, losses in growing crops have been estimated at about 18 percent.[18] Even approximate estimates for losses in underdeveloped countries are difficult to make. In Pakistan, the introduction of a control scheme for fruit in the North-West Frontier Province in 1949 quickly led to an increase in the supply of marketable fruit with a value many times the cost of the scheme.

A good example of a successful start in controlling serious diseases comes from Afghanistan, where grapevine is one of the most important crops and considerable foreign exchange is earned by the export of fresh and dried grapes to India and Pakistan. The powdery mildew of grapes is the most devastating disease in the vineyards. The disease appears in spring, and with the increase in temperature it spreads with such alarming rapidity that green bunches of grapes become crumbled and cracked in a short time and emit an offensive odor. In 1958, the disease caused an average loss of 50 percent of the grape crop in the Kohdaman area and almost 80 percent in Chardeh Ghorband and Kataghan. A conservative estimate is that the disease causes a total loss of about $5 million annually in Afghanistan.

During 1958, an FAO plant pathologist gave demonstrations in the Karazi-mir, Kohdaman and Deh-yaya areas on the control of powdery mildew with sulphur sprays and dusts prepared from local materials. Almost complete control of the disease was obtained on 25,000 vines in Karazi-mir, and almost 85 percent in the Kohdaman area.

The demonstrations convinced the farmers that this disease could be controlled by means of a suitable chemical. As a result, the Ministry of Agriculture established co-operative depots in 1959, from

[17] G. Ordish, *Untaken harvest*. London, Constable, 1952, p. 33.
[18] G. Ordish, *Op. cit.*, p. 40.

which farmers could obtain sulphur and dusting machines. Similar demonstrations were carried out during 1959, 1960 and 1961 and the results were equally satisfactory. In Deh Saby and Deh-yaya, the incidence of the disease in dusted vineyards was less than 3 percent, whereas in nondusted vineyards it attained over 50 percent.

In areas where demonstrations were made during 1958, the farmers have since adopted the sulphur dusting themselves. In Serai-Khoja, a conservative estimate reveals that the farmers in this area derived collectively in 1959 a benefit of over $1 million from dusting the grapes with sulphur.

Throughout history, extremely serious losses have been caused by locusts, and the Bible bears witness to the devastation which locust swarms often caused in ancient times. During recent years, much attention has been given to the control of the desert locust in southwest Asia and North Africa, and the locust of Central America and Mexico.

The desert locust is the widest-spread of the various locust species, with its migrations extending over 23 million square kilometers, thereby affecting the food and human welfare of one eighth of the population of the world living in over 60 countries. All these people face the common problem of locust control, but it has been affirmed by an international panel of experts that the matter can be solved in due course if regard is given to the scientific origins of the problem and to the technical ability of the staff of inflicted countries to make the fullest use of modern control methods. It is especially desirable that defensive strategy should change to the offensive, and to ensure joint international action and close co-operation between neighboring countries. Considerable advances toward these objectives are being achieved at national, regional and international levels, particularly through regional groupings and the United Nations Special Fund Desert Locust project.

At the regional level, an outstanding example during recent years has been the co-ordination by FAO of international anti-locust campaigns in the seasonal breeding grounds across the Arabian peninsula. The campaigns are conducted by the Governments of Saudi Arabia, Yemen and Kuwait, assisted by visiting missions from India, Jordan, Pakistan, Sudan, Syria and the United Arab Republic. Regional organizations also exist or are coming into being in eastern and western

Africa and in the Indo-Pakistan/Iran area. Through this widespread national and regional action, the desert locust is now attacked almost wherever it breeds at all seasons of the year. Locust swarms still continue to devastate the crops, but the weight of locust attacks now experienced generally falls well below those witnessed in the past.

A renewed international approach to the development of more effective and less expensive control of the desert locust was launched in 1960, when the six-year United Nations Special Fund Desert Locust project became operative, with the active participation of over 20 governments. This project, costing $3.75 million, aims at evolving a rational long-term policy of desert locust control and prevention through an integrated program of research and training.

Victory has been more easily obtained over *Schistocerea paranensis* Burm., which was recognized as the most serious pest attacking crops in Central America and Mexico. Prior to 1951, it was common for large agricultural areas to be completely devastated by swarms of this species. They attacked all crops encountered — cotton, sugar cane, banana, maize, cereals, fruits and vegetables. In order to integrate the efforts of infested countries in locust control, the International Committee of Co-ordination for Locust Control in Central America and Mexico (CICLA) was established in 1949. In one year these countries spent over $500,000 in control measures, but in spite of their efforts, crop losses were suffered. In 1951, FAO provided a locust expert to assist CICLA in research and other aspects of the problem. The Anti-Locust Department of the Organización Internacional Regional de Sanidad Agropecuaria (OIRSA) was created in 1955, and from 1957 to 1960 another FAO locust expert was assigned to assist this organization.

Through the co-operative efforts of FAO and OIRSA, local personnel has been trained for positions in research and in control operations. Public education and support for control programs have been achieved through posters, brochures, newspaper articles, field demonstrations, radio and other media. All of the OIRSA member countries now have their own locust control organizations.

Great savings in control operations and increases in food production have resulted from extensive surveys and studies of the biology of locusts made by the FAO experts. The location of many of the outbreak areas has made possible the destruction of incipient swarms

FIGURE 14. – A locust invasion. Dead locusts are immediately eaten by the survivors. If the dead locust has eaten poison bait, the eater will also die.

through properly timed applications of insecticides. Major outbreaks now occur only rarely and, after additional surveys, it is hoped that even these can be prevented from occurring in the future. The success of the locust control program in Central America and Mexico has been spectacular in keeping the pest population suppressed at a cost amounting to a small fraction of what the crop losses were before the initiation of the program. Through the efforts of FAO and OIRSA, losses in crops have been largely prevented, except very occasionally and in limited areas.

It is probably conservative to estimate that over the world as a whole, application of present knowledge about locust control would increase the production of food and animal feeds by some 15 percent, at the cost of only a small fraction of the value of the additional produce.

In this connection, it should be noted that in many, perhaps most, underdeveloped countries, specialized personnel to diagnose the causes of losses and advise farmers on the control measures necessary, or to organize and co-ordinate a concerted campaign against important outbreaks of pests and diseases, is very inadequate. Control measures are still often scattered and sporadic and therefore largely ineffective. Although the incidence of diseases and pests is sometimes not as heavy as in the more developed countries, where more intensive methods of agriculture provide a better habitat for them, those that do exist ravage almost unhindered. In the case of certain wide-ranging pests, particularly locusts, the efforts of national control organizations always need to be supplemented by international co-operation. As already noted, recent years have witnessed a major advance in such international co-operation in the Near East-Africa region and in Central America, under the auspices of FAO.

Effective control of weeds has an extremely important bearing upon crop yields, and in many countries weed control could by itself increase production substantially. This is particularly true in the tropics, where growth is so prolific but soil fertility often low. In experimental work in Ceylon, for instance, in connection with the "dry zone," it has been found that weed control by proper cultural methods is likely to be one of the single most important elements. The possibilities opened up by selective weed killers have as yet been little explored or utilized outside the more advanced countries.

Reducing losses through better storage and processing of agricultural products

Extremely large quantities of food, particularly grains, fruits and vegetables, animal products and fish are lost during storage, processing and transportation. Only a small proportion of the world's population is served by modern methods of grain storage which can keep losses from weevils, etc., to a very low rate, by refrigerated transport or storage for perishable products, or by processing facilities which can avoid heavy seasonal losses and spread the availability of supplies to consumers over the whole year. Although the need for such services is admittedly far less in more primitive economies, it is also true that their absence not merely results in postharvest losses but acts as a brake on production.

Although postharvest losses from inadequate storage, processing and transport are very large, it is difficult to estimate them even approximately. The FAO meeting on preservation of grains in storage (1947) estimated losses at around 10 percent of all stored grain. Even in the United States, grain storage losses due to rats alone are estimated at about 7 million tons annually, and losses from insects at between 8 and 16 million tons.[19] Losses are certainly much heavier in the tropics. In 1948, the FAO/ECLA Working Party on Agricultural Requisites, after a country by country survey, came to the conclusion that in Central America "lack of adequate storage facilities and of effective measures against insects and fungi" cause losses ranging from 25 to 50 percent of the harvested cereals and pulses. Even in the temperate countries of South America "losses incurred through lack of appropriate storage facilities and insufficient use of fumigants amount to at least 20 percent of the basic foodstuffs available for consumption." Although the situation has undoubtedly improved somewhat since 1946, it is evident that reduction of such losses can go a long way to make the world's scarce farmland stretch further.

Storage losses

The causes of spoilage and losses during storage are manifold, including enzymes in the stored product, "breathing" or germination of seeds, influence of air and water and action of micro-organisms

[19] FAO. *Second world food survey.* Rome, 1952, p. 31.

and insects. Most of these spoilage processes function only at a certain degree of moisture, so the two big practical dangers of all storage are humidity and insects.

It is useful to distinguish between direct and indirect losses during storage. Direct losses occur when part of the stored product vanishes, usually through the action of insects, and less frequently by chemical decomposition or spontaneous combustion; indirect losses are caused by spoilage, which either lowers the market value of the stored product, or even makes it unsaleable. Often the product can be used only for technical purposes instead of for human consumption, as in the case of rancid fats and oils, or the fats and oils with high free fatty acid content processed from spoiled oilseeds, which can only be used for such purposes as soap. Such indirect losses are still more difficult to estimate than the direct losses, but the resulting low prices not only reduce the standard of living of the farmers — they also discourage farmers from increasing their production.

To cite one example: In rice-growing countries, a second crop of groundnuts or soybeans can often be obtained after the traditional rice crop from the same area, but farmers are often not interested because of the low prices, especially if the harvesting of these products falls in the rainy season when, because of lack of suitable drying and storage facilities, the quality of the product is low and the dealers only pay reduced prices.

An important prerequisite of storage is the proper drying of the product to be stored. The usual way of drying farm products in underdeveloped countries is in the sun, often simply on mats in front of the houses or alongside the roads, or, on a bigger scale, on concrete floors made especially for this purpose. Artificial drying is practically unknown at the farmer and village level in these countries, except for special products like copra. Sun-drying can be quite efficient but is by no means ideal. For example, investigations made by FAO experts have shown that the percentage of sun-dried rice damaged by sun cracks is appalling. Even without regard to these special problems, sun-drying is very difficult and often almost impossible in the rainy season.

The installment of simple but adequate drying and storage facilities at the village level in developing countries is a tremendous and very difficult task for the future, but the potential increase in products available for consumption would be very large.

Processing losses

We can distinguish between three main groups of processing losses:

1. Losses by unripe, overripe, or faulty harvesting, which only appear during processing.
2. Direct losses in waste products and by-products.
3. Indirect losses as a result of faulty processing, with resultant products of bad quality.

There is a general tendency in developing countries toward unripe harvesting, usually caused by the poverty of the farmers, who are anxious to sell the crop as soon as possible. Examples are the unripe harvesting of coconuts for copra making, of sugar cane, of tubers like cassava, and even of typical seeds like groundnuts. As the unripe crops have a lower oil, sugar or starch content, the losses appear only in processing, and are often still further increased by the difficulties of processing unripe products. The size of these losses is not easy to assess but it is quite considerable. For example, it has been calculated in Thailand by an FAO expert, that more than 100,000 tons of sugar are lost every year by harvesting unripe cane. With better processing methods and better control, people will become more conscious of these losses, and there will be a growing influence on the farmers, from the rural industries, to improve harvesting and so reduce these losses, but improving the economic position of farmers is also important.

Direct processing losses occur in the form of by-products or waste products, such as oilcakes, molasses and bagasse, husks, bran, shells, parings, etc. In some cases, these by-products still have a certain value for feeding animals or for technical purposes, in others they have only fuel value; but in any case, they are lost for human consumption. A certain loss in processing is unavoidable but the losses are much smaller with modern processing methods and modern equipment. Modern expellers, for example, can reduce the oil content of the residue (oilcake) to about 4 to 5 percent and even lower, while with the more primitive equipment of developing countries the oil content of the cake is usually 8 to 12 percent, and sometimes considerably more, i.e., two to three times higher than necessary. In a similar way, sugar losses in bagasse can be many times higher by using inefficient,

primitive crushers, and molasses are not sufficiently exhausted if a modern scientific processing scheme in sugar manufacture is not applied.

Even in the case of a relatively simple act of processing, such as the shelling of groundnuts, the unnecessary losses of nuts in empty shells as the result of primitive equipment and faulty methods were found to be as high as 10 percent of the whole product.

Very often the extent of these losses is not known because of lack of control and insufficient facilities for analyzing the by-products and waste products, or because there is not enough trained staff available. Very frequently the first step toward reducing these losses is to improve control methods and let people realize what they lose financially.

Primitive and faulty processing also affects production indirectly, since products of bad quality get lower prices or are not marketable at all, with the result that the disappointed farmer reduces or stops production. Numerous examples could be given of the possibilities for improvement, especially in the field of fruits and vegetables; e.g., FAO experts have been able to improve date processing and packing in many developing countries and have shown better methods for drying grapes and figs and processing olives in some Mediterranean countries.

In the case of perishable crops like fruits, tomatoes and other vegetables, processing facilities in the form of canning, pickling, dehydration, etc., are a prerequisite for greater production. Another example is the cashew nut, a crop of high nutritive value, that has the advantage of growing even on rather bad soils but suffers in many developing countries from the lack of proper processing methods.

Some comparisons between crop yields in different countries

We turn now to consider some examples of the differences between countries in respect of crop yields and of total agricultural production per unit of agricultural land. To what extent do these differences reflect differences in the application of the techniques discussed above? What indication do they give us of the production possibilities if similar improvements in farming were made in other areas?

One of the striking contrasts in the world agricultural picture is afforded by the differences in paddy production per hectare in the various countries of monsoon Asia, even though the characteristics that meet the eye are so similar as to cause many a casual observer to believe that there is a high degree of uniformity in farming methods throughout the region. In fact, an analysis of the differences points the way to one of the major opportunities for stepping up per hectare yields over an immense area feeding nearly half the world's population.

These yields range from about 4.7 tons per hectare in Japan (1958-60 average) to 1.4 or 1.5 tons in India. Fairly high yields of around 3 tons per hectare are found in Korea and Taiwan, and yields apparently used to approximate 2.5 tons in China. It is claimed that yields have increased since. In other countries, they usually range between 1.4 and 1.75 tons per hectare. Differences in the degree of double-cropping may affect the comparisons in a minor way but actually the area double-cropped to rice in either Japan or China is very small, since temperature conditions make it difficult. The opportunities for double-cropping are far greater in the southern countries, wherever irrigation water is provided to tide over the dry season. Differences in climate may be a factor, since it cannot escape notice that the higher yields are in the three northern countries which enjoy temperate climate, as opposed to the tropical climate in southern Asia. The longer period of daylight during the growing season may be a factor in high yields.

On the other hand, there are extremely obvious reasons in farming practices for the differences in yields. Japan, for instance, uses 300 metric tons of plant nutrients in the form of inorganic fertilizers for every 1,000 hectares of cropland, while the rest of the Far East other than Japan and its former colonies of Korea and Formosa still uses only 3 tons, despite a rapid increase in fertilizer consumption in recent years in India and some other countries. Apart from mineral fertilizers, Japanese farmers use tremendous quantities of organic fertilizers, turning every scrap of plant, animal and human waste into composts or other organic manures, equal to nearly 40 percent of the total nutrients applied to the soil.

Outside Japan, former Japanese territories and China, practically no use has been made of these waste materials for fertilizer. Japan has 70 percent of its rice area under improved high-yielding varieties, chiefly as a result of intensive work on hybridization and a national program for multiplication and distribution of seed which provides pure seed each year to 30 percent of the area under rice. Few other countries, if any, outside former Japanese territories and reportedly Mainland China, have more than 10 to 15 percent under improved varieties. In most countries the proportion is much smaller. Only in one or two of these countries does the amount of pure seed distributed annually reach 5 percent of the total seed use, and in most it is negligible, often a fraction of 1 percent. Thus the standard of purity maintained in the areas under improved varieties is much lower. The varieties are also "less improved," being mostly selections from farmers' varieties. In Japan, highly improved varieties are available for every type of condition, with meticulous attention to minor differences and to the interrelationships between varieties, fertilizer responses, climatic conditions, soil conditions and water supply. In other parts of the Far East, improved varieties are available only for certain areas. The development of improved varieties, of knowledge of optimum fertilizer use and of interrelationships is based on an intricate network of research stations, one for each ecological region, substations and testing plots, absolutely without comparison in any other part of the region and perhaps in any other country in the world. As is well known, a controlled water supply is of the utmost importance for rice. Virtually the entire paddy area in Japan is under controlled irrigation, a much higher percentage than anywhere else. Finally, Japanese cultivation practices, including preparation of the land, planting and weeding, are of an exceptionally high standard.

In Korea and China also, farming practices may provide an explanation for the relatively high yields. In Korea, which was a Japanese colony for 40 years, the Japanese did all they could to increase rice production as a source of supply for Japan itself. Korea obtained the benefits of Japanese methods, including cultivation practices, use of improved varieties, and especially the intensive utilization of organic and inorganic fertilizers. At present, in South Korea, 109 tons of plant nutrient per 1,000 hectares are used in the form of mineral fertilizers. In Mainland China, the use of mineral fertilizers was negli-

gible until recently, and the development and use of improved varieties is in no way comparable with the situation in Japan. On the other hand, the careful conservation of all waste products for compost production or direct application to the soil has been a feature of Chinese agriculture for centuries and probably spread from there to Japan and Korea. This is in striking contrast with India and the other countries of southern Asia. Another major difference is that here also practically the whole of the paddy is grown under irrigation. Finally, the skill of the Chinese farmer is proverbial. The universality of irrigation, the intensive use of organic manures and the careful practices, along with probably a fairly high degree of farmer selection of varieties, may well be sufficient to account for the yields of 2.5 tons per hectare. Scientific plant breeding and a growing use of fertilizers would help to account for the still higher yields claimed recently.

Naturally, one cannot say that these differences in farming practices account for the full difference in yields between the various countries, but it is evident that farming practices could account for the differences and certainly are responsible for the major part of them. It is interesting in this connection to quote the conclusions of an Indian rice research worker after a tour of study in Japan: "Cultural methods have much more to do with the higher yields than natural conditions. What is known of cultural methods supports the view that yields in other countries could be raised to those of the better countries."[20] Apart from the fact that natural soil fertility in Japan is rather low, this conclusion finds strong support in the fact that Japanese yields were, within the period of historical record, not too different from those now prevailing in southern Asia, and that the increase has occurred *pari passu* with the application of scientific methods. Fortunately, historical data are available at least back to 1878, at which time yields were about 1.75 tons per hectare.[21] Japanese farmers were already using substantial quantities of organic manures at this stage and yields were rising at the time when statistical records became available. It is probable that earlier figures, say for 1850, would show a lower yield.

[20] N. P. Parthasarathy, *FAO fellowship report on rice agronomy in Japan*, October 1953.

[21] S.C. Salmon, Crop improvement in Japan. *Journal of the American Society of Agronomy*, November 1948.

FIGURE 15. – Japan: planting rice. With the help of more intensive use of scientific methods, Japanese rice yields have risen by over 20 percent since prewar.

The upward trend has certainly not ceased. Japanese yields averaged 4.3 tons of paddy per hectare over the five-year period ending 1958, compared with 3.6 tons during the last five years before the second world war (1934-38), an increase of nearly 20 percent. In 1960/61, they reached 4.86 tons per hectare and seem to be on the increase practically every year.

It is difficult to avoid the conclusion that the production potential of the 110 million hectares of paddy land in monsoon Asia (only 3 million are in Japan) are tremendous, if comparable use were made of high-yielding varieties and fertilizers, if the abundant water supplies of southern Asia were harnessed and general cultural practices improved. Indeed, if yields throughout the region were brought up to the Japanese level on the area at present devoted to rice, total production would exceed 500 million tons of paddy compared with a production of around 220 million tons in 1960/61. In south and southeastern Asia, attainment of Japanese yields would raise production from 117 million tons in 1960/61 to 360 million tons! In fact, it is most unlikely that there would exist a need at any time in the foreseeable future for so much rice. Rising per hectare yields for paddy would make it possible to devote more area to alternative crops, including animal fodders. This is the road that must be taken if Asia is to achieve a more diversified agriculture and a more diversified diet.

It may be contended, of course, that the Japanese yields, while high per unit are low per man, and are only achieved by means of painstaking care for every bit of ground. It is true that the productivity of agricultural labor in Japan is low by western standards, as is shown by a paper submitted by FAO to the last world population conference, *Fundamental factors affecting the stage and status of agricultural development.*[22] It is not, however, unduly low by the standards of agriculturally backward areas, output per head of agricultural population being then 80 units in Japan compared with 50 in India, 58 in the Philippines, 85 in Mexico and 95 in Yugoslavia. It is, of course, higher in those countries of the Far East where the main concentration has been on export crops, as in Ceylon and Malaya.[23]

[22] P.G.H. Barter, Fundamental factors affecting the stage and status of agricultural development. *Proceedings of the World Population Conference, 1954*, Vol. 5, p. 189-214.

[23] See P. G. H. Barter, *Op. cit.*, for explanation of units used.

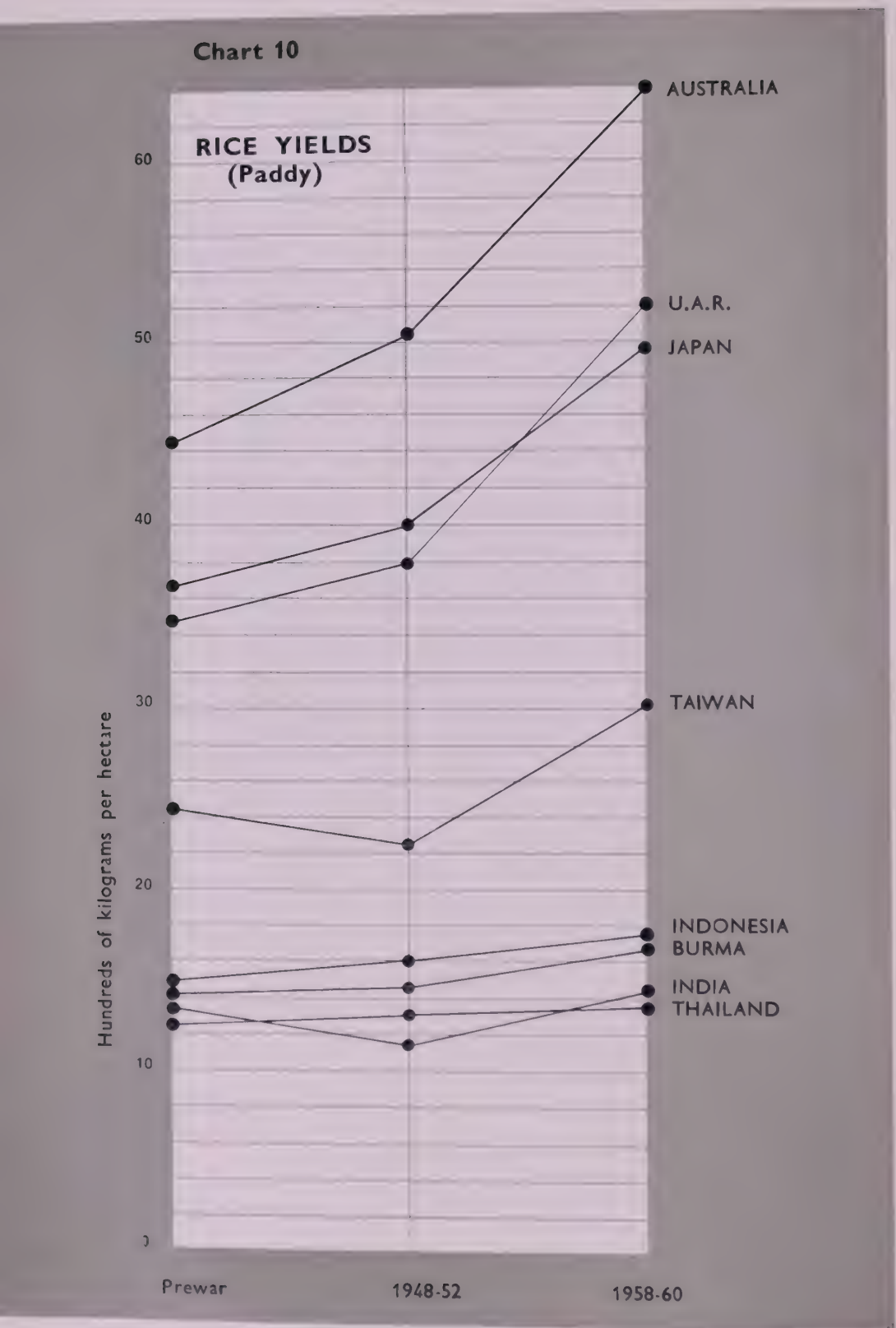


Chart 10
RICE YIELDS
(Paddy)
AUSTRALIA
U.A.R.
JAPAN
TAIWAN
INDONESIA
BURMA
INDIA
THAILAND
60
50
40
30
20
10
0
Hundreds of kilograms per hectare
Prewar
1948-52
1958-60

Actually, while meticulous care of the crop is undoubtedly a factor, the main elements in the high yields are undoubtedly the use of fertilizers, utilization of the results of plant breeding, and controlled water supply. The low labor productivity is imposed by institutional factors, particularly the small farms and the minute size of the individual plots, often formed by terracing the hillsides. The Japanese yields for rice are by no means unique. The fact that they do not necessarily require backbreaking toil is illustrated by the fact that in Australia, for instance, where the labor input is extremely small by Asian standards, but fully scientific methods of culture are followed, the average yield is over 6 tons per hectare. The yield per hectare is between 5 and 6 tons in Italy, Spain and the United Arab Republic, and actually exceeded 6 tons per hectare in Spain before the last war.

Aggregate production per hectare in the Far East

It is possible that the disparity between Japan and the rest of monsoon Asia would be even greater if the comparison were made in terms of total agricultural production in relation to agricultural area, instead of in terms of individual crop yields, since Japan grows over $1^1/_3$ hectares of crops per year on every hectare of arable land, whereas a great part of the area of southern Asia lies idle for some six months of the year. This disparity is greatest in the case of countries such as India, which devote most of their area to basic food crops. In fact, the comparison between Japan and India in respect of total agricultural production per hectare of arable land equivalent is in Japan's favor to the degree of 6 to 1.[24]

The Japanese ratio of crop hectares to arable area is achieved in the face of limitations set by low temperatures, whereas in southern monsoon Asia, temperature conditions would permit double- or even triple-cropping, were sufficient moisture available. The extent to which this may eventually prove practicable will depend, of course, upon the feasibility, from the engineering standpoint, of bringing the abundant supplies of water which certainly exist to bear on the arable lands at economic rates. There is no doubt that a very large proportion of the arable area of southern monsoon Asia can be given an as-

[24] See P. G. H. Barter, *Op. cit.*

sured round-the-year water supply. In respect of that part of the cultivated area which can ultimately be brought under perennial irrigation, there is therefore reason to believe that the combination of highly scientific farming practices, assured water supply and a year-round growing season may well result in an output per hectare substantially exceeding that of Japan, since each hectare could be cropped up to three times per year. However, in India, shortage of water supplies on the Deccan plateau and elsewhere leaves extensive areas where the Japanese level of output per hectare could not be approached.

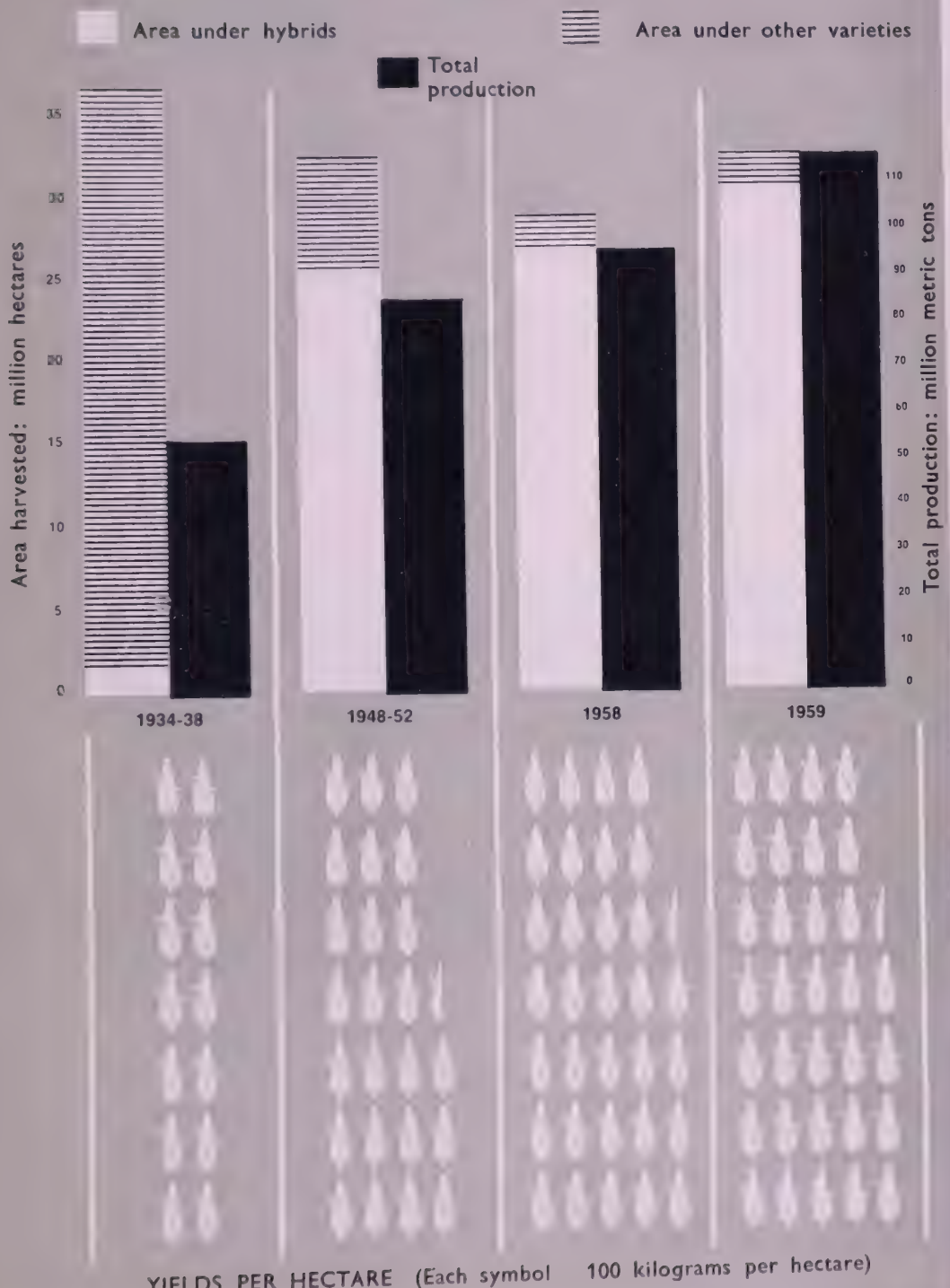
Maize

The development of hybrid maize, as a result of the brilliant work of plant breeders in the United States, opened up entirely new possibilities for higher yields of this crop. There is probably no other situation in which one could say with as much confidence that from the point of view of agricultural science major gains in production could be achieved by the fuller application of existing knowledge.

Principally as a result of the use of hybrids, the average annual production of maize in the United States increased from 53 million tons over the five years 1934-38, when already a small proportion of the area was under hybrids, to an average of 82 million tons over the five years 1948-52, on an area 12 percent smaller, and of which some 80 percent was occupied by hybrids. In 1960/61, it was 110 million tons. While average weather conditions may have had some influence, the increase in yield of a major crop from 1.5 tons per hectare in 1934-38 to 2.5 tons in 1948-52 and 3.3 tons in recent years must be one of the most remarkable changes in agricultural history. In a sense, of course, the whole of the gain in yield cannot be attributed to the superiority of the new varieties. Since hybrids require more plant nutrients, they have intensified the whole rotation and deeply affected all farming practices, including particularly the level of fertilizer usage. But the fact is that the existence of the superior varieties has created both the opportunity for much higher yields and the stimulus for better farming.

The introduction of hybrids has completely changed the ranking of the United States in the world in respect of maize yields per unit area. Before the war, yields were lower than the average in Europe

Chart 11. - HYBRID MAIZE IN THE U.S.A.



and Latin America, and only 15 percent above those of Asia, even though hybrids were already in partial use. United States yields prior to the introduction of hybrids and the practice of heavier fertilization were therefore comparable with the world average. Since the gain from 1.5 to 3.3 tons per hectare is attributable to a clearly defined improvement in cultural practices, there is no reason to suppose that it cannot be repeated elsewhere. Technically, the opportunity exists and one can say with good reason that similar changes in farming practice would be likely to result in yields comparable with those found in the United States, which are by no means the highest in the world. Such a development would mean an increase in world production of maize (excluding the United States) from 114 to 250 million tons. This would include a three- to fourfold increase in Africa, where maize yields are extremely low in most parts, owing to very primitive methods of cultivation.

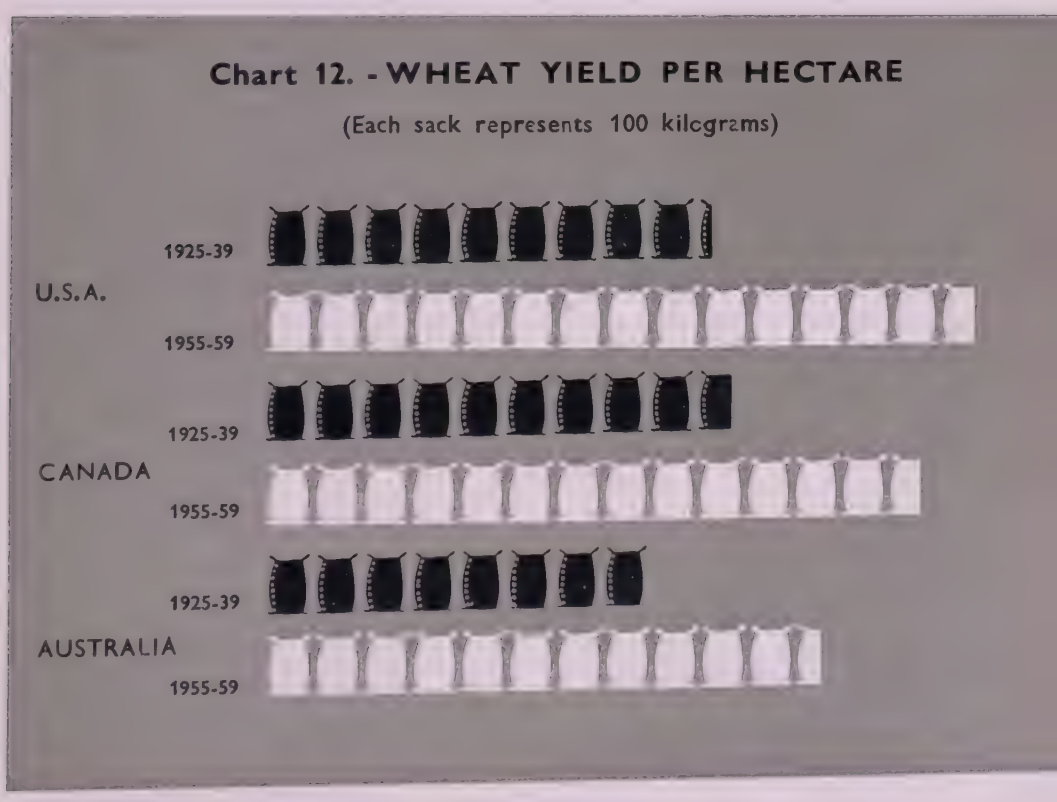
Wheat

Although average wheat yields could certainly be raised greatly by improved farming methods, without incurring uneconomic inputs, it is more difficult than in the case of rice and maize to find existing standards by which possibilities may be measured. Wheat yields range from an average of around half a ton per hectare in several of the underdeveloped countries, to 3.5-4.0 tons in a few countries of northwestern Europe, with a world average of 1.2 tons per hectare.

The European yields can certainly not be taken as an indication of yields obtainable by methods which would be economic in many of the main wheat-growing areas of the world, particularly those countries which produce for the world market. Most of the wheat in western Europe is heavily protected and high in cost. It should be noted that the high cost of European wheat is not wholly attributable to uneconomic inputs but is also due to institutional factors. Many of the benefits of European rotational and cultural practices could be obtained in other parts of the world, without necessarily incurring the disadvantages of small farms, fragmented holdings and labor-intensive methods.

On the other hand, a very large proportion of the world's wheat area is used on a wholly or almost wholly monocultural basis with

or without mineral fertilizers. Under this fertility-depleting cereal/cereal or cereal/bare fallow rotation, a balance is reached often at a fairly low level of productivity per hectare between the nutrients removed by each crop and those added to the soil by nature or man. The introduction of an improved rotation, such as legumes, grasses and/or mixed crop/animal husbandry economy leads quickly in many areas to much higher yields. It is a matter of major interest that in recent years wheat yields in the United States, Canada and Australia have been appreciably higher than during the 1920s and 1930s, when no clear trends were evident. Whereas yields averaged between 0.8 and 1 ton per hectare in these countries over the period 1925-39, they have recently (1959-61) been around 1.7 tons in the United States, 1.3 tons in Canada and 1.25 tons in Australia. During the three years ending 1961, average wheat yields exceeded those of the 1925-39 period by 58 percent in Australia, 84 percent in the United States, and 29 percent in Canada. Better weather may have been a factor in this improvement but it is unlikely that it is a major factor.



This is certainly a subject which would justify careful study, but in Australia at least it would appear that the trend which is evident in recent years away from monoculture in the wheat belt, with greater attention to leguminous pastures, is partly responsible. In Canada, more timely eradication of weeds, a practice which it has been shown can make a difference of up to 35 percent in yields, has been a contributing factor.

In Latin America, Asia (excluding Japan) and Africa (excluding the United Arab Republic and the Sudan), no significant change is to be noted from the traditional yields of between $^3/_4$ and 1 ton per hectare.

While the following figure is quite arbitrary, it seems not unlikely that if wheat were normally sown as part of a soil-fertility building rotation, along with a system of mixed farming, taking full advantage of mineral fertilizers, using varieties bred for the higher yields possible under these conditions, and with proper control of weeds, an average yield of 2 tons per hectare could be obtained under conditions adapted to wheat, at costs per bushel not greater than those now incurred. Such yields could not, of course, be obtained on some of the drier lands which are at present growing wheat.

Millet and sorghum

These crops are grown mostly in Asia and Africa, where little or nothing has been done to select or develop high-yielding varieties, almost entirely without benefit of fertilizers and frequently with crude cultural methods. It is not surprising, therefore, to note that in the United States, sorghums produce 2.5 tons per hectare, compared with just over half a ton in Asia and Africa, where the crop is mainly grown. In fact, United States yields used to be very close to those in the underdeveloped countries. Millet yields average about 0.6 ton in Asia and Africa. No really good check on possibilities is available as in the case of sorghum, but indications in a few countries are that millets also will respond to breeding and better practices.

Cereals (summary)

The comparative survey of cereal yields, while admittedly very rough, suggests that if farmers throughout the world were in a position to grow improved varieties adapted to their conditions, took

advantage of modern knowledge regarding soil fertility, and followed generally good cultivation pratices, production of cereals in underdeveloped regions could be doubled and perhaps tripled on the present area or, alternatively, the present production could be obtained from half or one third of the present area. These conclusions assume costs per quintal not higher than present costs and undoubtedly average costs would be considerably lowered, while making immense areas of land available for other crops and pastures.

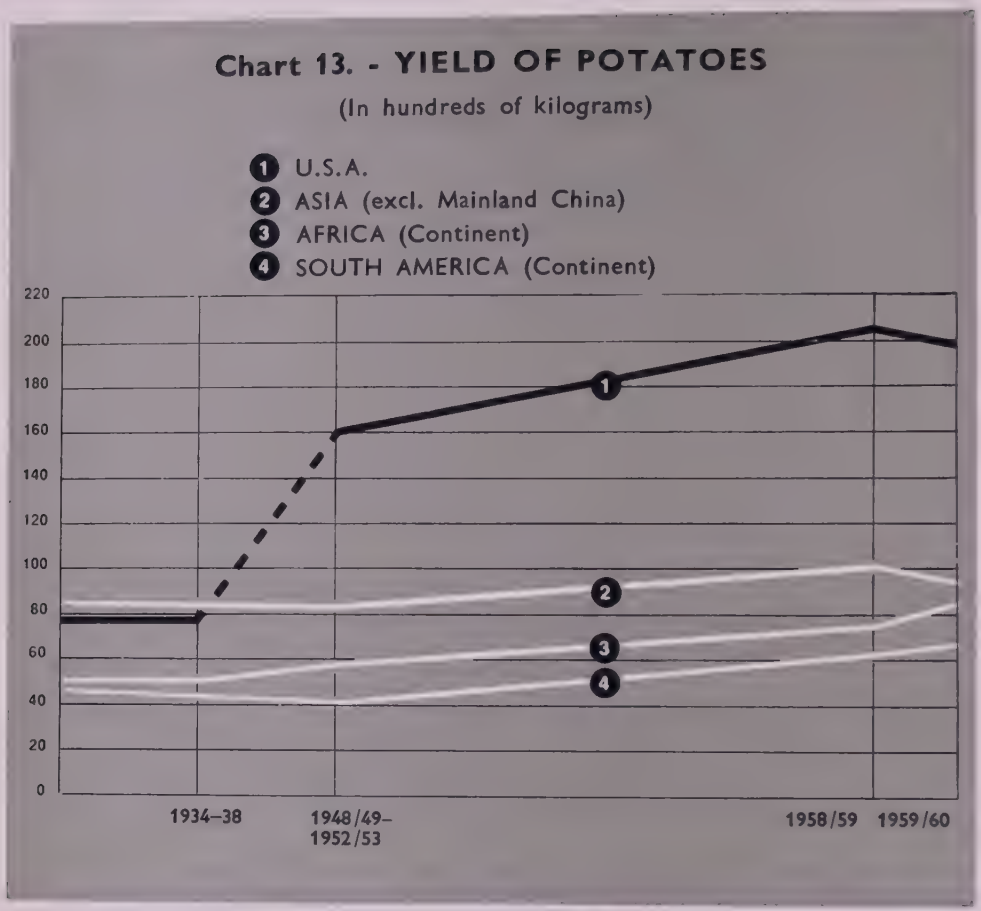
Selected other crops

It is not easy statistically to extend to a wide range of crops the yield comparisons that have been made in the case of cereals, nor is it necessary to prove the general point. A few comments on some crops of major significance may, however, be worth while.

White potatoes provide another example of a crop where major advances have been made by farmers in a few countries but the scientific progress which lies behind this has not been utilized by farmers elsewhere. In the United States, prewar yields of 7.8 tons per hectare were roughly comparable with those in Asia, Africa and Latin America. Within a period of 15 years, United States yields were pushed up to 16 tons per hectare, and have now reached 20 tons, largely as a result of better control of pests and diseases.[25] If yields in the three underdeveloped continents mentioned above were comparable with those now prevailing in the United States, where labor inputs are much lower, the production of potatoes in these three regions would approximate 50 million tons as against present production of less than 20 million tons. There is an example in Peru of an Indian farmer in the Altiplano who, by following the advice of the joint United States-Peruvian extension service, has raised his yields to six to seven times those of his neighbors.

In sugar cane, average yields of around 5 tons of sugar per hectare harvested are obtained in Cuba and many other countries, and 20 tons in Hawaii. Yet in India, the yield is about 3.5 tons, and in Pakistan just over 2 tons per hectare. As in the case of rice in monsoon

[25] Byron T. Shaw, The role of research in meeting future agricultural requirements. *Agronomy Journal*, March 1953.



Asia, it is probable that differences in varieties, fertilization, other cultural practices and processing techniques have more to do with these yields than differences in natural conditions.

Yields of dry beans appear to range from about 200 kilograms per hectare to 2 tons. Once again, the United States yield of 1.25 tons per hectare probably gives a good indication of what can be achieved with present knowledge under actual farming conditions, with relatively low labor inputs per unit area. The potential for greater production of pulses per hectare in many underdeveloped areas through breeding and better fertility practices is certainly very great indeed.

Yields of cotton lint per hectare in the United States fluctuate between 2 and 3 quintals. In China they come to about 3 quintals and in India 1 quintal. The average for Africa (excluding the United Arab Republic) is 1.3, and in Brazil it is 1.5. A yield of 300 kilograms

per hectare is probably generally practicable under nonirrigation conditions, given good varieties and good cultural methods. This suggests that Asia and Africa could double their production from the existing area by improved practices.

The gap between knowledge and practice

So far, yield comparisons have been made against those achieved by the average farmer in a country where inputs are considered to be economic in relation to those prevailing in other major producing countries. In fact, the yield achieved by the average farmer is usually well below what is possible by using the best practices, even in a country where farmers are well educated. This could be illustrated in all countries by comparing average yields with those obtained by the best farmers, not necessarily under more favorable natural conditions. It is shown repeatedly in farm competitions and also by government experiment stations, though these results are often subject to suspicion as to whether they have been obtained by methods which would be economic under farm conditions.

A few examples which are conveniently available from the United States illustrate how great the gap often is between average farm practice and the present frontiers of knowledge. In Iowa, the average maize yield in good years reaches 38 quintals per hectare compared with 82 quintals in the Iowa variety tests; average potato yields in Maine have reached a high of 320 quintals per hectare, compared with 620 in the variety tests; average wheat production in Ohio is around 17 quintals per hectare, as against variety test yields of about 38 quintals; while in South Carolina average cotton yields of 4.5 quintals of lint per hectare compare with yields exceeding 18 quintals by the winners of the state cotton contest.[26]

These examples probably tend to exaggerate the differentials between knowledge and practice, because the test results may be obtained under better than average conditions. However, in a broad way, they do illustrate the point that even where social, economic and institutional conditions are most favorable to the adoption of new techniques, great possibilities remain for raising yields by fuller or more

[26] Byron T. Shaw, *Op. cit.*

widespread application of existing knowledge. In fact, it is considered by agricultural authorities in the United States that a reasonable potential yield for the crops mentioned above in the states specified would be 82 quintals of maize in Iowa, 34 quintals of wheat in Ohio, and 9 to 11 quintals of cotton lint in South Carolina.[27]

[27] Private communication from Dr. Byron T. Shaw, Administrator, Agricultural Research Service, United States Department of Agriculture.

4. POSSIBILITIES OF INCREASING OUTPUT OF LIVESTOCK PRODUCTS

It is probable that the potentialities for increasing the output of milk, meat, eggs and wool per unit of livestock are relatively greater than those for increasing crop yields, since, except in western Europe, North America, Oceania and the temperate part of Latin America and Africa, livestock improvement has been almost entirely neglected until very recently as a result of the concentration upon sufficient high-calorie food to maintain life and health. It is also rather easier to judge the potentialities for livestock improvement than for crop improvement by using the yields achieved in the most advanced countries as a standard, since there is a considerably greater assurance in the case of livestock that the high yields are obtained as a result of breeding and better practices which technically could be repeated elsewhere. In fact, the high levels of livestock performance in the regions mentioned above can be traced to deliberate policies of livestock improvement which had their inception in Europe in the middle of the eighteenth century, from where the various breeds and management practices have spread to the regions mentioned above, and in many cases have been further improved.

In the following pages, it is proposed first to discuss briefly the contributions which better control of diseases, a more scientific approach to feeding, and purposive breeding programs could make to raising the productivity of livestock, including particularly the production of more milk in warm countries; secondly, to give some indication of the potential for raising average yields per head as judged by achievements in the more advanced countries; and finally, to consider to what extent the potential feed resources justify an eventual increase over present livestock numbers. At the same time, it is stressed that the objective is not maximum production per animal but maximum production per hectare.

Technical measures for increasing productivity

The main fields of activity which influence livestock productivity are disease control, feeding, breeding and management. In the absence of a reasonably efficient veterinary service, the losses caused by disease are so great that they discourage any real activity on improving the nutrition of animals or breeding. An adequate feed supply of suitable nutritional value is necessary if animals are to produce up to the limits of their biological capacity. When diseases are under control and there is adequate feed to take advantage of animals with high output potentials, breeding becomes important. Management is related to each of these three fields. Because of the special importance of milk for nutrition, special reference will also be made to achievements in selected areas in the tropics in developing a productive and hygienic dairy industry.

Disease control

The losses caused by disease, and the types of disease mostly responsible for such losses vary greatly from region to region. In the more advanced countries, debilitating diseases such as foot-and-mouth disease, mastitis, brucellosis and parasitic infestation are the most serious, essentially because the animals are better bred and because normally they are better fed. In the less developed areas, it is the lethal diseases such as rinderpest, hemorrhagic septicemia, Newcastle disease and protozoan diseases (sleeping sickness, tick-borne diseases) which must be brought under control if any progress is to be made.

With few exceptions, the control measures for these diseases are now well understood and can be economically applied. In particular, very considerable progress has been made during and since the war in the production of more effective and cheaper vaccines.

Until recently, foot-and-mouth disease caused very heavy losses to European agriculture and the epizootics of the disease showed a tendency to become increasingly serious. The most devastating which ravaged Europe in recent times occurred between 1937 and 1940, when the total number of outbreaks was almost 2 million. At about this time, however, an effective vaccine was produced and its use under proper conditions has proved to be a factor in the control of the disease. By a combination of vaccination, slaughter of infected herds and strict

veterinary police measures (isolation, movement restrictions and disinfection), it has been possible for many European countries to bring foot-and-mouth disease well under control. This combination of methods seems to be the modern approach toward the control of this serious disease of livestock. In several countries, particularly the Netherlands, Denmark, Austria, Yugoslavia and Greece, all invasions of the disease since 1953 have been effectively stopped without serious losses. When these methods of control are practiced in all European countries, the time will have arrived when it will probably be possible to bring the disease completely under control throughout the whole of the continent. FAO and the European Commission for the Control of Foot-and-Mouth Disease, both by direct contributions of equipment to various governments and by consultations, have contributed in a large measure to the present favorable situation.

Mastitis is another debilitating disease which causes tremendous losses in the production of milk throughout the world, these being variously estimated at between 10 and 15 percent in most advanced countries. Besides the loss of milk, mastitis reduces the effective life of the cow, so that more replacements must be obtained. New and more effective methods of treatment and control, when applied in some of the advanced countries, have resulted in a substantial increase in milk production. Even among advanced countries, there are many areas in the world where modern techniques for the control of mastitis are not being applied.

There are no figures available on the total losses caused by brucellosis in cattle throughout the world, but the widespread incidence of this disease results in a heavy loss of calves and milk. Brucellosis of goats and sheep also causes tremendous losses, particularly in the Mediterranean region, where recent figures in Tunisia indicate that the annual loss in goats and sheep in that country reaches almost 50 percent of the goats and almost 20 percent of the sheep infected, and that in some areas as much as one third of the human population suffer from the disease. In the United States, it has been calculated that the reduction in the incidence of brucellosis by more than 50 percent has resulted in a saving of more than $50 million annually to the livestock industry. This disease is important not only from the point of view of loss of livestock products but also from the infection of the human population, including reduced efficiency of the farmer. In

some countries, brucellosis has been eradicated or greatly reduced with much economic benefit, as shown above in the case of the United States. Between 1948 and 1960, the percentage of cattle infected was reduced from about 4.5 to a little over 1 percent. The number of human brucellosis cases (undulant fever) dropped from over 6,000 to under 1,000. There is no technical reason why it could not be generally eradicated. In Norway, for instance, the total cost of eradication was approximately $2 million, compared with annual losses from the disease of approximately the same amount.

It is difficult to calculate the losses due to internal parasites in all types of livestock. The problem is so widespread that parasitologists in general would agree that if existing knowledge on control of parasites were applied in the advanced countries, total livestock production would probably be increased by approximately 15 percent.

There are many other debilitating diseases (e.g., tuberculosis) which occur throughout the world to a greater or lesser extent, for which there are mostly effective means of control and, in some cases, eradication.

As regards lethal diseases, the advances made in the control of rinderpest in the last decade and a half have been indeed outstanding. With the development and application of cheap effective vaccines, the establishment of laboratories and the training of personnel for the production of vaccine, widespread outbreaks of this disease could be avoided if all countries were in a position to apply effective controls. It is estimated that the losses in the Far East from this disease were approximately 2 million head of livestock per year before the national and international rinderpest control campaigns were launched after the war. The losses in recent years have probably not been more than 50,000 head. However, the recent invasion of India, where measures for eradication were already well advanced, from Nepal, shows how necessary it is to have complete participation of all countries if success is to be achieved. Because of the presence of rinderpest in certain countries and because of the great risk in importing animals or meat from such infected countries to regions that are free of the disease, such as Europe, surplus livestock from infected areas (e.g., Ethiopia) is not available to those areas deficient in meat. An effective control program on a regional basis over a period of a few years would make it possible to eradicate this disease completely. This has already

been accomplished in certain countries, such as South Africa, the Philippines, the Federation of Malaya, and Thailand. Intensive efforts toward control and eradication are being made at present in many countries in Asia and Africa, in several of them under technical guidance from FAO.

Mortality from hemorrhagic septicemia in some areas, particularly in the Far East, is as high as 50 percent of the livestock in some years. The figures given on the losses caused by hemorrhagic septicemia in various parts of the world are far from accurate, but they have been estimated at an average loss of about 1 million head of livestock. Up to the present time, a really preventive vaccine has not been produced, but with the development of the new adjuvant vaccines, more efficient immunization can be expected.

Important advances have been made in recent years in the control of Newcastle disease in poultry, known as ranikhet in the Far East. Although there is still much to be done, a great deal has already been accomplished. In the Far Eastern region, outbreaks of this disease used to result in 70 to 100 percent mortality, and hence control with cheap effective vaccines is essential before commercial poultry farms can be established. A typical example of this is Singapore, admittedly a very small area, but where reasonably accurate figures are available on the poultry industry. Prior to 1947, a cheap effective vaccine was not available in that area. The government then produced locally a cheap and effective vaccine. There were at that time 500,000 head of poultry on the island, practically all in small flocks of 10 to 12 or less. By 1952, as a result of the control of Newcastle disease, commercial flocks had been established and numbers of poultry had risen from 500,000 to 3.5 million, an increase of 600 percent. Egg production, however, increased by 800 percent, and it is interesting to note that the cost of eggs remained stable through that period, despite the fact that all other commodities had increased in price considerably. A similar type of program, for which figures are not yet available, has been going on in the Federation of Malaya, Thailand, Cambodia and parts of India. Official government reports made to the *Animal health yearbook*, published by FAO, show a much reduced incidence of the disease.

In Africa, the potential for beef production is enormous but at the present time great tracts of suitable land cannot be used by livestock

FIGURE 16. – An FAO poultry specialist demonstrates the technique of inoculating a bird against Newcastle disease.

because of the presence of the tsetse fly. There is little doubt that scientists will eventually evolve a satisfactory control plan.

The high incidence of ticks in many parts of the world appreciably reduces animal production through tick worry and loss of blood. However, much more important is the fact that in most parts of the world they also transmit protozoan diseases, which in many areas result in the loss of large numbers of livestock. Although the tick has been eradicated from certain areas of the world, the problem of its eradication cannot be solved completely in other parts because of the environment. However, with the application of modern techniques of control, the losses can be reduced to small proportions.

Better feeding

A vast body of knowledge has been developed on what constitutes scientific feeding for various classes of livestock. This relates both to the quantities of food which animals should receive at various stages of development and also to the balance of the ration, which, having regard to economic as well as technical nutritional relationships, will yield the greatest return per unit of feed expenditure.

Basic to all scientific feeding is the fact that unless the level of feeding goes beyond a certain point, the feed consumed leads to no productive return whatsoever from the human point of view. An animal purely on maintenance ration will not produce livestock products, or will produce very little. In other words, the maintenance ration serves mainly to keep the animal alive, so that such food fed to an animal is virtually wasted. It is food over and above the maintenance ration which begins to give returns in milk, eggs, growth, etc. For instance, poultry fed an inadequate but above-maintenance ration produce fewer than 60 eggs per year. An increase, very frequently of little more than 25 percent in the ration, can result in a 100 percent increase in egg production. Milk production in particular suffers quickly from a decline in feeding and, provided the biological capacity of the cow is adequate, responds rapidly to relatively small increments in the amounts fed. For efficient livestock production, therefore, an animal should be fed the maximum amount which it can effectively and economically utilize for conversion into livestock products.

At the present time, by far the greater proportion of the world's livestock is fed very little more than a maintenance ration for a large

period of the year. The most outstanding example of this type is the maintenance of livestock on pastures, particularly in the less developed areas. There, the pastures, as a result of seasonal rains, are good enough to supply the foodstuffs for the livestock only for a short period of the year. At the end of the rains, the grass grows to maturity very rapidly and provides little more than a maintenance ration for the livestock. With continued grazing, which is not controlled, the ground is left bare and frequently soil erosion follows. Actually, in most areas of the world, during the growing period of the herbage there is a surplus beyond the requirements of the livestock grazed on the area. The cutting of this herbage will maintain it at a higher nutritive value for livestock, as well as increasing the total quantity of foodstuffs. The herbage cut and properly stored, either as silage or hay, will supplement the pasture and prevent overgrazing during the dry period. Thus with proper management, it is possible not only to maintain the livestock on a higher plane of nutrition but also to increase the carrying capacity of the land and to increase efficiency of livestock production, as well as reduce the losses from soil erosion. Professor Kay of Reading has estimated that milk production per cow or buffalo could be increased threefold by better feeding alone.

Even in advanced countries, a very large proportion of the livestock is not fed sufficiently to obtain the maximum amount of livestock products from the foodstuffs fed. Only in relatively restricted areas of the world, principally in northwestern Europe and in parts of North America, does the general body of farmers pay much attention to the balance of the ration.

Therefore, it may be said that in most parts of the world, animals are not being fed enough to enable them to make use of their biological capacity to produce, low though this often is in many areas. An improvement in feeding conditions, especially if accompanied by more attention to a better balance of nutrients, would generally give results in output considerably more than proportionate to the increased quantities of feed used.

In most cases, increasing the production of beef cattle, dairy cattle and sheep is a relatively slow process, involving a gradual improvement of feeding, breeding and management practices, and the maintenance of the health of the herd or flock. However, in many areas of the world, and particularly in many countries where technological

developments are less highly advanced, mineral deficiencies of an unknown nature are the major deterrents to livestock production. In such areas, systematic research leading to a disclosure of the specific deficiencies involved, and therefore in most cases to the removal of the limiting factors, has been shown repeatedly to result in a several-fold increase in both the efficiency of livestock production and in total livestock production within very short periods of time.

Surveys conducted by FAO experts in several Latin American countries have made it apparent that millions of hectares of otherwise excellent livestock production areas are rendered unfit or marginal for economic livestock production due to mineral deficiencies and imbalances. Other areas of the world are similarly affected. The most economical, rapid and certain way to solve these problems is by employing established investigational procedures with the animals which are affected.

For example, there is the case of the development of the " 90-mile desert " area in Australia. The Australian Mutual Provident Society, with the co-operation of the Governments of South Australia and Victoria, embarked in 1949 on developing an area known as the " 90-mile desert. " Investigations revealed that the unproductiveness of the area was due in great part to a deficiency in the soil of micro-nutritional elements which could be corrected by the application of small amounts of copper and zinc sulphates and phosphates.

The development was achieved in three stages. The first was the removal of the scrub, plowing, preparation and seeding of the land, along with application of fertilizer. About 340 kilograms of superphosphate in four doses and 3.2 kilograms each of copper and zinc sulphates per hectare were used. The land was then sown with a mixture of legumes and grasses, about 1.8 kilograms of legumes and 0.34 kilogram of grass per hectare. The second stage consisted of top-dressing the pastures, erecting fencing and creating water facilities. The third stage, which is continuous, consists of maintenance and proper utilization of pastures and conservation of fodder. Conservation of the spring flush for consumption during the autumn achieves maximum year-round carrying capacity.

In place of the near-worthless scrub, supporting (after a burn) for limited periods perhaps 1 dry sheep to 8 hectares, the pastured country is suited for fat lamb raising, wool growing, beef production,

and some dairying. As soil fertility is built up, odd crops, mainly oats and barley (with some wheat on the heavier soils), form part of the ley farming method of land use. Ultimately, many farms will become more of a mixed farming proposition, with the better class of country having a potential the equivalent of 3 dry sheep to the acre (7.5 sheep to the hectare).[1]

Another example of mineral deficiency is found in the Amazon valley, where it causes losses of livestock and prevents the proper maturing of beef and dairy stock in spite of apparently lush pastures. At present, large-scale experiments are being conducted with such trace elements as copper and cobalt, which are highly promising. If these experiments are successful, it is probable that a vast area will be opened up to large-scale rearing of cattle.

Breeding

As in the case of plants, the purpose of livestock breeding is to raise the biological capacity of the animal to produce, that is, to increase the efficiency of conversion of feedstuffs into milk, eggs, meat and wool. Also, as in the case of plants, the ability to withstand adverse climatic conditions, such as in the tropics, is an essential objective in many parts of the world. There are very great differences between the animals in the efficiency of conversion both within countries and between countries, but in general it can be said that the difference between the average animal in the less developed countries, principally in the tropics, and in the most advanced ones, is often tremendous.

Even in the more advanced countries, in the temperate climates the average quality of the livestock could be greatly improved through a more widespread application of the principles of selective breeding, that is, by keeping careful record of performances, culling the poorer animals, and concentrating on the better ones for breeding. The development of artificial insemination techniques greatly facilitates this, since it makes it possible to concentrate on the very best sires and thus speed up the process. In the less advanced countries, particularly in the tropics, very little has been accomplished by way of

[1] Private communication from the Australian Mutual Provident Society.

upgrading livestock to compare with the progress which has been made in Europe and some of the newer countries over the last 200 years. There are, however, a few outstanding exceptions which indicate that fine breeds of livestock can be developed for the tropical regions, as, for example, the Santa Gertrudis in Texas, certain herds of Sindhi and Sahiwal cattle in India, Boran and other breeds in Africa, certain breeds of buffalo in the United Arab Republic and India, and the herds of Friesian purebreds and crossbreds in Israel. The potentialities for raising the productive capacity of livestock in the underdeveloped regions either by selective breeding from the few superior animals which usually do exist, by crossbreeding with European types, or by importation and adaptation of European breeds where environmental conditions are favorable, are very great.

Solving milk production and processing problems in warm countries

The problem of supplying milk to the people of many underdeveloped countries is acute. The shortage and high cost of supplies, coupled with the low purchasing power of the majority of the people, results in such a low consumption of milk or other protein-rich foods as to make malnutrition a widespread and serious problem.

The problem is also one of real urgency for the immediate future. According to figures published by the United Nations in *The future growth of world population*, by 1965 there will be an additional 65 million children under 15 years of age in those countries usually referred to as technically underdeveloped. If adequate milk supplies are to be ready for these extra children, production of milk in underdeveloped countries will need to expand at the rate of 50,000 liters per week!

In these circumstances, special attention must be given to the problems of milk production and processing which can be said to be special or characteristic for warm countries. In some countries, milk collection and distribution schemes have been inaugurated. Technical personnel has been obtained through FAO and other organizations for assisting in various dairy schemes, as, for example, in cheese-making projects in the remote mountains of Nepal. A milk board has been set up in Colombo to cope with the problem of milk supply for that city, and milk colonies have been established in several cities in India.

An interesting example is the development in the village of Anand in India just north of Bombay. The villagers were steeped in the old traditions; men, women and children worked long hours for pitifully small returns. For generations their water buffaloes had produced abundant supplies of milk; in fact, at certain times of the year there was too much milk for local mouths to consume and a glut on the market resulted, while at other times there was no milk to be had even for their own children.

In 1945, the Government of Bombay launched a scheme to supply milk from Anand to city consumers. During the initial stages of the scheme, however, the collection of the milk and its processing were left to contractors and private dairies, and very little of the increase in price offered by the government was received by the farmers. In their dissatisfaction, they organized the first village co-operative society. Eventually, other societies from surrounding areas joined to form the Kaira District Co-operative Milk Producers' Union.

At the beginning, the people felt the existence of the co-operative only through the modest extra sum that they were receiving for their milk, but there were much bigger plans under way for the growing union. They wanted a way to dispose of the surplus milk accumulated during the flush seasons: the answer was a large dairy factory capable of converting the surplus milk into other products.

The completed dairy factory at Anand, the first plant in the world to dry, powder and so conserve the milk of the water buffalo, stands as testimony to one of the greatest co-operative ventures of our time. The Kaira Union provided the land and the buildings; the Government of New Zealand, under the Colombo Plan, donated some dairy equipment and provided technical advisers, as did FAO. Over the years, UNICEF has donated some $180,000 toward the cost of milk storage tanks, refrigeration equipment and various other evaporating and drying equipment. This was done with the understanding that the plant would make free rations of milk available to mothers and children in the area — an obligation which has been fulfilled.

Today, the Anand plant collects milk from 40,500 farmers from more than 195 villages. As much as 24 million kilograms of milk were collected during the year 1960/61 for the production of dry milk, pasteurized liquid milk, butter, cheese, casein and baby foods.

The Kaira Co-operative Union, begun on a small scale by people

FIGURE 17. – Arrival of milk at the Anand milk plant. Over 115,000 liters of milk are handled each day.

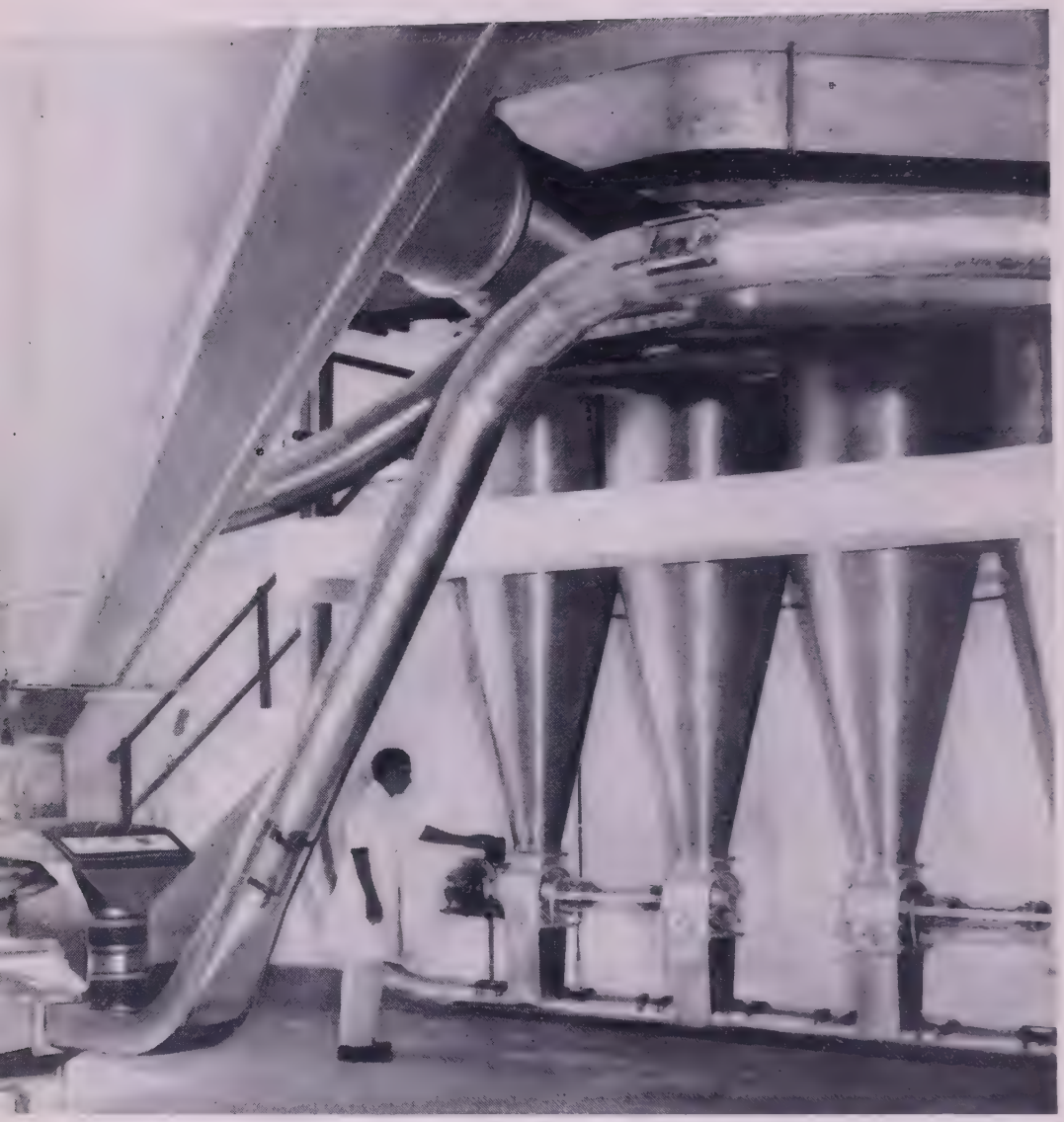
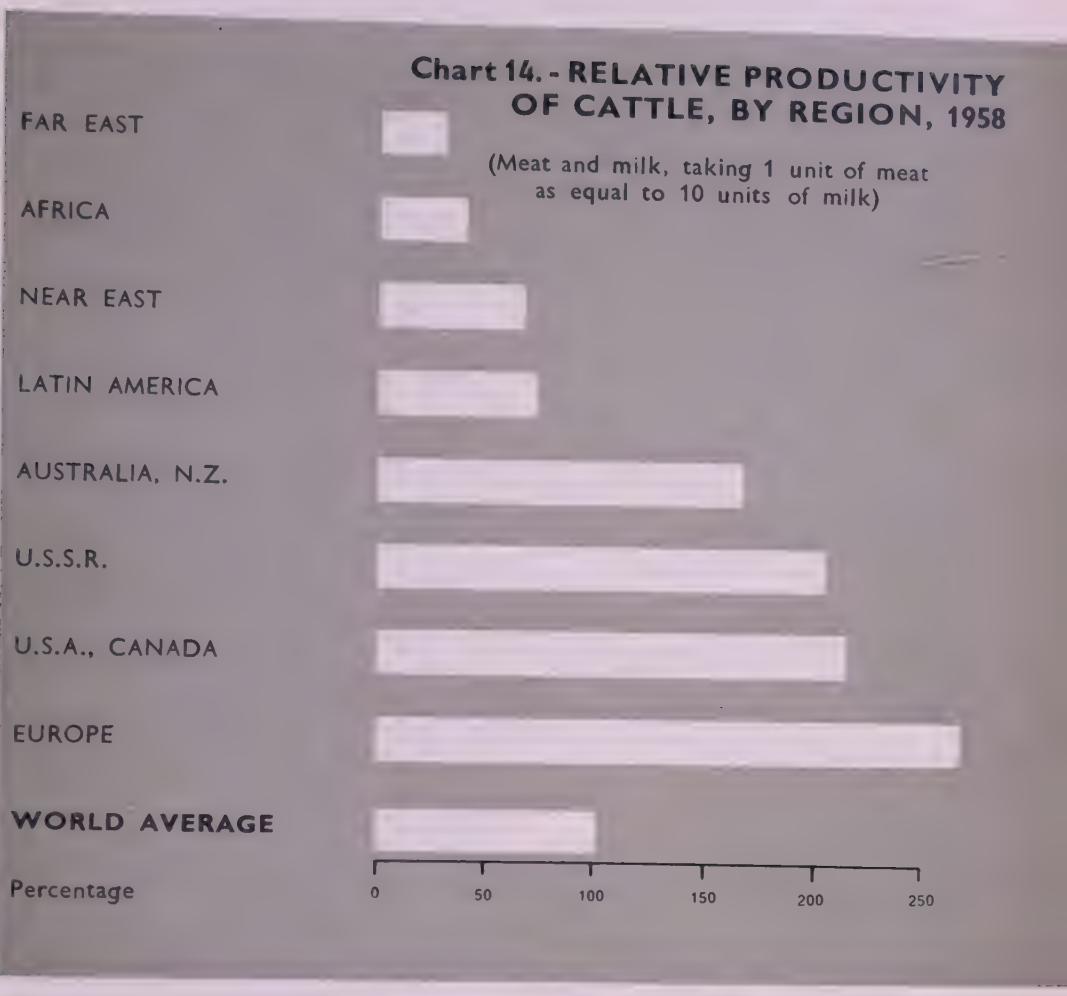


FIGURE 18. – Part of the spray milk powder plant at the Anand co-operative dairy, the first in the world to process the milk of the water buffalo.



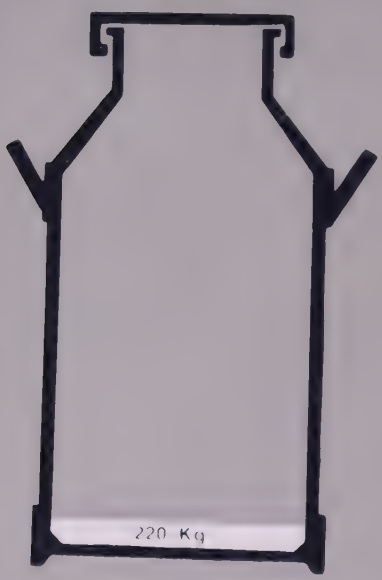
dissatisfied with their poor circumstances, will turn over approximately $4 million worth of dairy products a year.[2] With sufficient funds for the equipment for similar dairies, these results can be duplicated in other areas.

Some comparisons between livestock yields

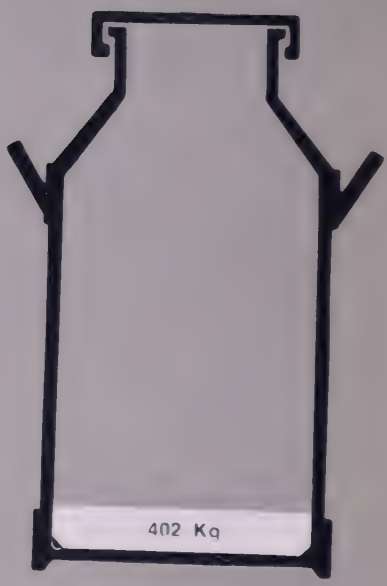
As a consequence of careful breeding over a long period of time, research and its application in the control of diseases, improvement of pastures and scientific feeding, the spread between the more advanced and less advanced countries in yields of milk per cow, wool per sheep, meat per animal per year of growth and eggs per hen has grown stead-

[2] *Technical Assistance Newsletter,* April 1959.

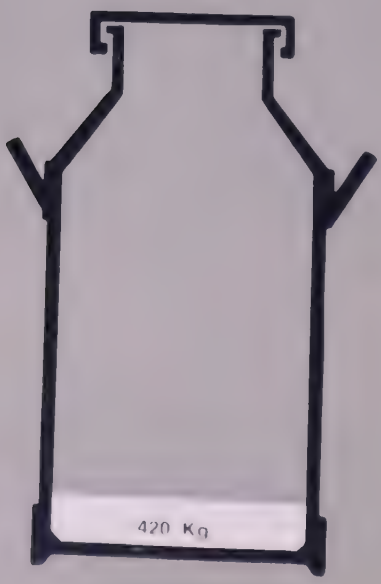
Chart 15. - MILK YIELD PER M



INDIA



TURKEY



PAKISTAN

FED. OF MALAYA

V, VARIOUS COUNTRIES, 1958

ISRAEL

NETHERLANDS

BELGIUM

DENMARK

ily greater over the last two centuries, and the gap continues to widen. Theoretically, these yield differentials, taken together with livestock numbers adjusted either upward or downward according to what appear to be the potential feed resources, given improvement and proper management of pastures and utilization of other feeds available without competing with products needed for human food, afford the basis for estimating the potential production of animal products at present levels of knowledge. In practice, numerous difficulties — deficiencies in statistics on livestock performance, lack of adequate surveys on potential feed resources, and methodological problems arising out of the fact that most animals serve several purposes (e.g., meat and milk, wool and meat, draft and milk), impede any such estimate. Nevertheless, the general picture is becoming sufficiently clear to make possible a first rough approximation. Both the techniques and the results will naturally be subject to major adjustments in the years to come. By the time a reasonably precise estimate of production potentials is possible, the theoretical potential will undoubtedly be considerably higher than it is now, because of increased knowledge.

Cattle

Perhaps the best illustration of differences in livestock productivity is given by the yield of milk per milking cow. Even among the most advanced countries differences are very great. The Netherlands, which until recently had the highest output per cow, had a milk yield in 1960 of 4,280 kilograms per cow in milk, compared with 3,180 in the United States, 2,990 in the United Kingdom, 2,140 in France and 2,020 in Australia. Thus, taking the Netherlands as 100, the production per cow was 75 in the United States, 70 in the United Kingdom, 50 in France and 47 in Australia. Generally, yields are much lower in the underdeveloped countries, being usually less than 1,000 kilograms and sometimes only a few hundred kilograms. Unfortunately, few countries offer precise figures and these are probably rather unreliable, but the figures for Peru, Burma, Iran, Pakistan and Turkey, which happen to be available, range between 402 and 760 kilograms. In some countries the yields are apparently even lower.

Meat production per animal, even where herds are raised for beef, also differs greatly because of differences in carcass weight and the number of years taken to reach maturity.

Unfortunately, it is neither statistically nor technically possible to compare the efficiency of cattle in different countries in terms of a single product. Statistics rarely distinguish beef from dairy cattle and in many parts of the world no such distinction actually exists. Even where there is a clear-cut distinction, a considerable part of the beef may come from dairy herds. The relative importance of milk, meat and draft power differs tremendously from country to country.

One is therefore confronted with the problem of attempting to find a common measure for these different products. While the soundest scientific basis would be provided by their relative cost in terms of feed units or starch equivalent, existing information does not permit the use of this method. Another basis for comparison is afforded by their calorific value, but the results do not adequately reflect their relative cost in terms of resources. The third alternative, which is used here, is to take a price-weighted index. Unfortunately, it has not been possible to include draft power in the general calculations for lack of data, but a rough check has been made in the case of the Far East of the extent to which the results are modified by including draft power.

In Table 3, figures are given for the number of cattle in each region, the production of meat and milk, and the combined production of both in terms of milk equivalent, if a price ratio of beef to milk of 10 to 1 be assumed. The final column shows the combined output in relation to the number of cattle and therefore affords a measure of the relative productivity of the cattle in the different regions.

While admitting that both the statistical and the methodological foundations for these calculations show serious gaps, it is believed that the results do succeed in measuring in a general way the comparative levels of productivity of cattle in the broad regions of the world. The last column in Table 3 would indicate that output per head is ten times greater in Europe than in the Far East, seven times greater than in Africa, and four times as high as in the Near East and Latin America. Even in Oceania, the index of productivity is only 60 percent of that for Europe. However, allowance must be made for the fact that in the less developed regions large numbers of cattle are used as draft power. The omission of this factor is, of course, unfair to the underdeveloped regions. A rough estimate for the Far

TABLE 3. – CATTLE NUMBERS AND OUTPUT, BY REGIONS, 1958

Region	Cattle	Production		Units of output [1]	Ratio of Column 5 to Column 2
		Meat	Milk		
	Million head	.... *Million tons*			
Europe	108	5.9	119	178	1.65
United States - Canada	104	7.2	65	137	1.32
Australia - New Zealand	23	1.2	11	23	1.00
Latin America	185	5.9	19	78	0.42
Far East [2]	344	2.9	27	56	0.16
Near East [2]	34	0.6	7	13	0.38
Africa	102	1.5	8	23	0.23
U.S.S.R.	67	2.7	57	84	1.25
World	967	27.9	313	592	0.61

[1] In terms of milk equivalent, taking 1 unit of meat as equal to 10 units of milk.
[2] Including buffaloes.

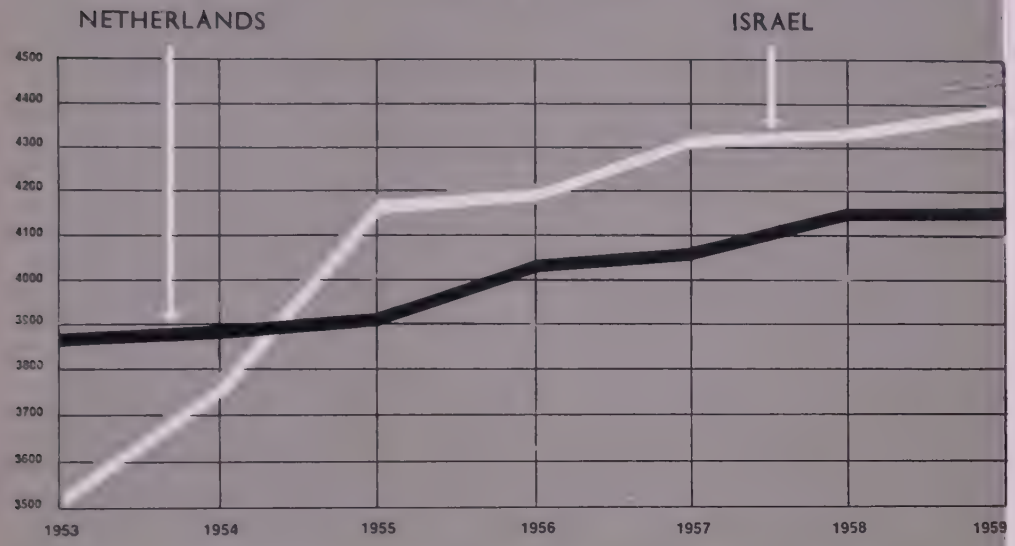
East shows that the output of draft power is probably about equal in importance to that of milk and meat combined. Inclusion of draft output would also make a substantial difference in the Near East and Africa, though probably proportionately much less. It would raise the Latin American ratio somewhat and raise that of Europe very slightly. Thus, as well as diminishing but not greatly lessening the differential between the more developed and less developed regions, the inclusion of draft power would bring the Far East more closely into line with the Near East and Africa. The Far East would, however, still probably show the lowest level of productivity, because of the tremendous number of useless or almost useless cattle in India.

It would, of course, not be correct to assume that all regions in the world could attain the same level of productivity as Europe, mainly because of climatic factors. The European figure is, however, itself an average, with much higher levels being generally attained in the west and much poorer results in the east and the Mediterranean area. In fact, the index for the Netherlands is 2.6, and even here there is scope for increase in productivity on a large proportion of the farms.

It is quite evident, therefore, that there remains a big potential for increased output of milk and beef even from present cattle numbers

Chart 16. - TRENDS IN MILK YIELDS PER MILKING COW

(Kilograms per year)



in the more advanced countries. The efficiency of production for Europe as a whole is not high when one considers the possibilities from prevention of losses, correct feeding, proper management and breeding. It would be reasonable to suppose that the rest of the world could at least attain present average European standards of productivity in respect of cattle, perhaps approximately 1.5 units of output per head. In North America, Oceania, parts of Latin America and in the western U.S.S.R., it would be possible to approach closer to the levels of western Europe.

One can therefore draw the conclusion that, given the same level of application of modern technology in respect of control of diseases, improvement of pastures, feeding, management and breeding, as in the case of the average European farmer, total output in terms of milk and meat from herds of existing size could certainly be several times as great as at present.

The most remarkable proof of this comes from what has been achieved in Israel over an amazingly short period of time through a planned program of selected breeding, feeding and management of cattle.

The result has been to put the Israeli herds of Friesian purebreds and crossbreds into first place in the world of milk production, despite the fact that, from a dairying point of view, climatic conditions in Israel are unfavorable. The yield figures (in 1960) show:

Israel	4 380	kilograms	per cow	per year
Netherlands	4 280	"	"	"
Belgium	3 810	"	"	"
Denmark	3 710	"	"	"

The extent of the improvement obtained in milk yield in Israel is illustrated strikingly by the fact that cows of the few local breeds left in Israel only produce 620 kilograms of milk per year.

In its policy and programs aimed at making the Israeli dairy industry the most modern in the world, the government has worked in full co-operation with the Israeli Cattle Breeders' Association (CBA) and has sought to exploit as much as possible the limited land area of Israel by developing a high-producing national milk herd and, at the same time, raise cattle for meat.

This has led to the introduction of methods for the strict testing and recording of performance of both cows and bulls. Only those bulls whose progeny give the highest and best quality yield of milk and beef are selected for breeding, which is carried out by artificial insemination.

Milk recording in Israel had its beginnings in 1926 but official recording was only started in 1934, while its use in assessing the breeding value of bulls dates only from 1950. This shows the astonishing progress achieved in a relatively brief time through the introduction of performance testing and recording. Almost 40 percent of the national milk herd is recorded at present but the government plans to extend such recording, particularly as about 90 percent of breeding is by artificial insemination. Milk records, which are as nearly complete as possible, are essential for the proper evaluation of bulls being used in this service.

Sheep

Equally interesting conclusions can be drawn, with perhaps a higher degree of assurance, regarding potentials for wool production.

FIGURE 19. – An Australian Merino ram. While the average clip is approximately 4.5 kilograms per head, individual rams are known to yield over 20 kilograms.

When the first Merinos were brought to Australia in 1810, the best of the flock cut approximately 1.10 kilograms of wool. Since then, principally by selection and control of diseases and parasites, the average clip has been raised to 4.5-5 kilograms, and for 1960/61 it was 5.7 kilograms in New Zealand, where feed conditions are much better. It should be emphasized that, on the whole, feed conditions in Australia are not good, though they could be greatly improved, while the upgrading of the flocks has been a slow but persistent process, carried out by the owners themselves with very little help from scientists. The upward trend shows no signs of slackening off, the cut per sheep averaging 4.12 kilograms in the five years ending 1943/44 and 4.45 kilograms in the five years ending 1950/51. In 1953, an all-time record of 4.98 kilograms per sheep was attained, to be repeated in 1959. The present average is greatly exceeded in the case of many larger flocks on big stations, where special attention has been paid to breeding and other factors, with average clips of around 7 kilograms for flocks running into hundreds of thousands of sheep being attained. Individual rams have cut over 20 kilograms of wool.

Generally speaking, in the Far East, Near East and Africa (apart from South Africa), conditions have changed little over the period during which this remarkable transformation has occurred in Australia. The clip per sheep averages about 1.10 kilograms in the Near East, 0.90 kilogram in the Far East, and is apparently even lower in Africa, excluding South Africa. The average is about 1.80 kilograms in Europe and the U.S.S.R., nearly 2.70 kilograms in Latin America, and over 3.60 kilograms in the United States. The world average is very close to 1.35 kilograms.

Here again, any one figure taken as an indication of the potential would be arbitrary. For one thing, where the main emphasis is on mutton and lamb, the cut of wool will be lower than in the case of sheep kept principally for wool. This explains some of the differential between the Australian average and the figure of 1.95 kilograms in the United Kingdom. Elsewhere milk is a principal objective. There can be no doubt, however, that the possibilities for increased wool production through a policy of selective breeding, control of parasites and diseases and better feeding are really tremendous. Even in the more advanced sheep-breeding countries, such as South Africa and Uruguay, production per sheep is only two thirds to three quarters

of the Australian-New Zealand level. If the cut per sheep throughout the world were at the same level as in Australia, total production from present flock numbers would be more than three times what it is at present. In using this as an attainable standard under present levels of knowledge, one might bear in mind that the greater concentration on meat and milk in some other areas is offset by the fact that the practicable level of achievement in Australia on a mass scale has been shown to be well above the present average.

While no study has been made of the position in respect of mutton and lamb, it is evident that here too production could be multiplied by breeding, better feeding and control of disease.

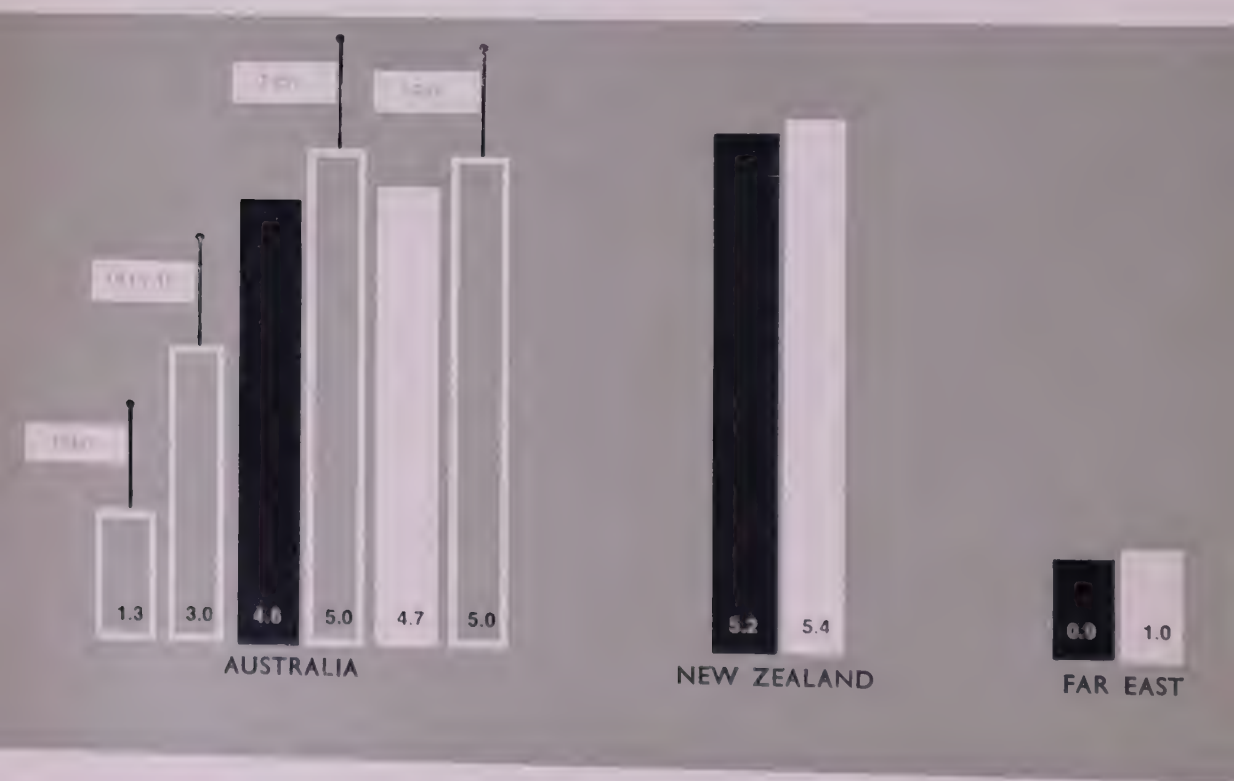
Other livestock

In the case of pigs, as with cattle, there are great differences in different parts of the world in the size of the grown animal, in the period required to reach maturity, and in the amount of weight put on per unit of feed consumed. There are also wide variations in feeding practices and control of disease. In many parts of the world the pig is a very small animal, only a fraction of the size of the breeds now used in the most advanced countries, but perhaps very similar in weight to the animals from which the efficient modern breeds of porkers and baconers have been developed.

The same applies to poultry, whether viewed as egg producers or table birds. Statistics on egg production per hen are particularly scanty but sufficient to indicate that there exists a very wide range, while statistics in a few countries show that steady progress is being made in raising output. In a few countries where most of the farmers have good birds and use good methods of management, for instance the Netherlands, the number of eggs laid per hen is around 160 a year. In some countries for which statistics are given, though probably not very reliable, it is as low as 40. Others are found at all points along the range between these two figures. As an example of steady progress, one may quote the United States, where production per layer was 121 eggs in 1929-33, 154 in 1945/46 and 202 in 1957-59. The progress in that country in terms of requirements of feed per pound of live weight is equally striking. In 1947, a total of 5.5 kilograms

of feed produced a 1.4 kilogram broiler within 13 weeks, which is a feed conversion rate of 3.9. In 1961, best commercial rations gave broilers of 1.95 kilograms in 8 weeks from 3.6 kilograms of feed, which is a conversion rate of 1.85. This data may be contrasted with the more common feed conversion rates of 5 to 6 in many developing countries. It is not difficult to conclude that in developing countries the use of newer techniques in breeding, better feeding and control of diseases could easily double egg production in terms of numbers, and much more than double it in terms of weight, from flocks no greater than those at present existing.

In conclusion, it is clear from differentials in livestock performance, that even without increasing animal numbers, the general application of existing scientific knowledge to the same extent as it is applied by the *average* farmer in the countries which have made most progress, would provide about a threefold increase in output of livestock products. The complete application of knowledge would, of course, result in a much greater volume of production.



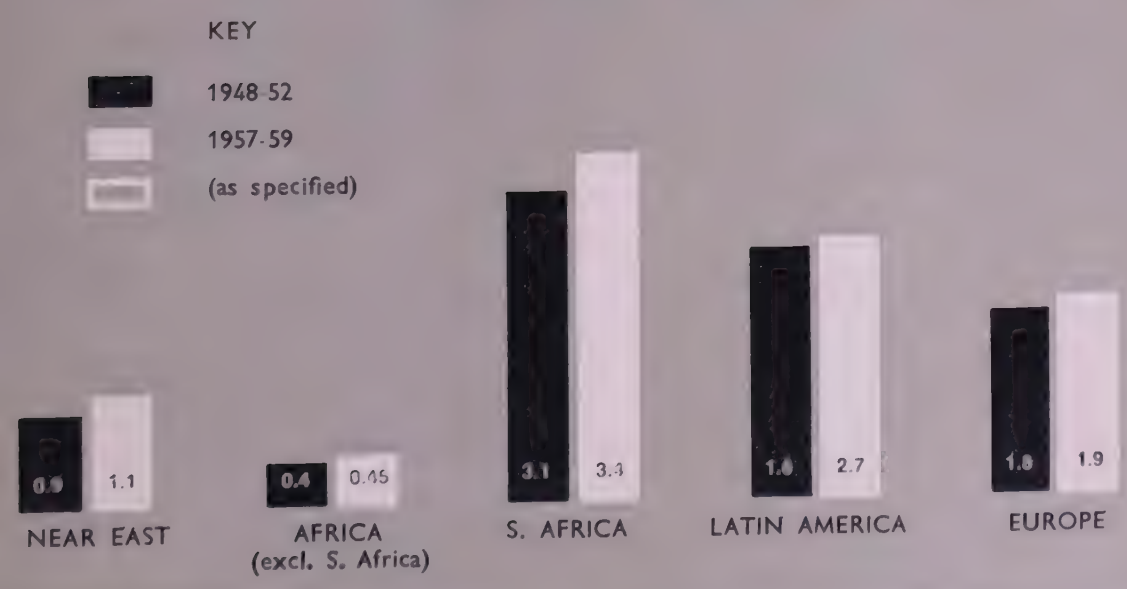
Livestock numbers and improvement of grasslands

So far, we have considered production potentials in terms of present livestock numbers. The limiting factor in livestock numbers is, of course, feed supply. Is there a sound basis for a further expansion of livestock population? Or may not livestock numbers be already higher than can be safely maintained in the long run? One common point of view is that, as the human population increases, it will be necessary to devote a larger proportion of land to growing crops for direct human consumption, since much of the energy is lost in the process of conversion from plant to animal product, the recovery of calories ranging from only 4 percent in the case of beef and mutton to 7 percent for eggs, 15 percent for milk, and 20 percent for pigmeat. Another view is that in many parts of the world animal numbers are such as to lead to serious overgrazing, with resultant soil erosion.

It is true that animals do compete with humans for a proportion of their feed supply, that the efficiency of conversion is low, and that

Chart 17. - WOOL CLIP IN SELECTED COUNTRIES AND REGIONS

(Kilograms per sheep per year)



overgrazing is an extremely serious problem in many areas. Nevertheless, it is beyond question that world livestock numbers could safely be greatly increased, provided concurrent attention is paid to improving the feed base. It has already been shown that the potentialities for raising crop yields are so great that a much larger rather than smaller proportion of the available land area could be devoted to producing livestock feed. As for overgrazing, this is in most instances the result of poor pasture management rather than absolute overstocking, though reduction in numbers may often be a necessary first phase in improvement of pastures. It is recognized that much of the earth's surface is suitable only for the production of fibrous plant material which is best utilized by conversion to animal products.

In assessing feed resources, it is necessary to consider cattle and sheep, which secure most of their food from grazing, separately from pigs and poultry. In the latter case, there is no fundamental difficulty about a very great increase in numbers, provided that effective use is made of waste and by-products, with grains being fed where resources permit and, where needed, to provide a balanced ration. In particular, the opportunities for increasing poultry numbers by utilizing waste products and without drawing seriously on the human food supply are almost unlimited. With effective organization of potential feed resources, very great increases in pig and poultry numbers would be possible with very little competition in terms of land area. The possibility of increasing the carrying capacity in terms of livestock is a basic question in any study of food production potentials and deserves special attention. It is therefore proposed to examine this subject in more detail.

Improvement of grasslands

Grass provides the bulk of the feed for the world's herds of cattle and flocks of sheep and is the source of most of the world's meat, milk, wool and leather. The improvement of pastures is therefore the most important factor in increasing the number of livestock which the feed resources are capable of supporting on a sustained yield basis, as well as being one of the main factors in raising the productivity of livestock in terms of a given area of land.

There is probably no other major aspect of farming in which average practices are as backward as in the management of pastures. " In

fact for the majority of farmers grasses have not yet become a crop, but have remained a mere source of natural roughage, while most arable crops have engaged men's attention over hundreds or thousands of years."[3] The general principles of pasture improvement and management in the temperate zones are now fairly well understood and are practiced to varying degrees by farmers in northwestern and north-central Europe, where the standards of grassland farming are most advanced. A great deal has been done also in the United States and Argentina, especially by way of establishing improved pastures (e.g., alfalfa) in the more humid areas. Progress at an accelerating rate has occurred in the last quarter century in the United States, Canada, southern Australia, New Zealand and South Africa in pasture improvement, but in general it may be said that such work is still only in the early stages. Even in the more progressive farming regions, great scope remains for increasing the quantity of feed that is produced by the existing areas under pasture, while throughout most of the temperate grasslands of the world the productivity of the pastures could be doubled, and frequently multiplied several-fold, by the application of existing knowledge. In the tropics, a great deal remains to be discovered regarding the most suitable grasses and legumes and their management, and very little indeed has actually been done to raise the productivity of the native grasses. It is difficult therefore to say what may yet be possible but there is no doubt that productivity could be raised greatly through application of existing knowledge. Wahlen makes the point, however, that at least for some time to come, " the very poor nutritive value of grasses and the lack of research on grass and legume combinations in many areas rich in leguminous plants may make continuous supplemental feeding necessary for acceptable milk and meat yields" in the tropics and subtropics.[4]

In considering the potentials of grasslands, it is important to distinguish between the extensive areas of rangeland, much of it of relatively low rainfall or suffering a long dry season, and the well-watered areas where grasslands are either integrated with the cropping system or capable of being so integrated.

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[3] F.T. Wahlen, Grassland resources and potentials of the world. *Proceedings of the Sixth International Grassland Congress, 1952*, Vol. 1, p. 103-113.

[4] F.T. Wahlen, *Op. cit.*, p. 108.

FIGURE 20. - Ethiopian cattle on poor grass.

FIGURE 21. – Some excellent pasture in Kenya. The cows shown above yield some 2,275 liters per lactation.

In the first case, the possibilities for improvement are more limited, while the dangers of actually reducing carrying capacity by misuse are extremely great. As Wahlen has pointed out, many of these natural grasslands "are among the most vulnerable climax associations existing."[5] Unrestricted or inadequately controlled grazing has done enormous damage to the pastures of the western half of North America, Australia, the whole Mediterranean and Near East region and of extensive areas of Africa and Latin America. While the number of livestock supported by pastures and supplementary feeding in the more humid temperate regions has steadily increased, the number carried in the lower rainfall areas has generally declined. For instance, in Australia, the number of sheep carried in the Western Division of New South Wales decreased from 16.4 million at the time of the 1891 census to 5.5 in 1901, and has never since exceeded 8 million head, owing to deterioration of the grass cover. In the western half of the United States, "where there was grass up to the stirrup of the cowboy fifty years ago, enough to nourish 300 cattle to the square mile in the estimation of the early rancher, there may be only mesquite and bitterweed today."[6] The system which has been worked out by range management experts in the United States for appraising potential productivity recognizes that some range is at present able to carry less than a quarter of its potential, considering rainfall and soil.[7]

One of the major possibilities for increasing livestock numbers consists therefore in the restoration, where possible, of the pastures of the semiarid lands to their original carrying capacity, followed in some cases by their further improvement through introduction of more productive species and fertilization where these measures are economic. FAO is paying a great deal of attention to the restoration and improvement of the indigenous pastures in the Mediterranean and Near East regions, where they have been seriously misused for centuries. The measures by which it is hoped to increase the productivity of the pastures in this region may be taken as fairly typical of the measures necessary under similar conditions throughout the world.

[5] F.T. Wahlen, *Op. cit.*, p. 105.

[6] F.T. Wahlen, *Op. cit.*, p. 106.

[7] A.T. Semple, *Improving the world's grasslands*. FAO Agricultural Studies No. 16, 1951, p. 43.

The first requirement is adjustment of the stocking rate to the carrying capacity of the grasslands. This should be such as to permit the maintenance or the improvement of the grass cover. In some cases, improvement of the vegetation may necessitate complete protection from grazing during one or more seasons. Deferred grazing during the growing season until plants have matured seeds also benefits recovery. Utilization of the desirable forage plants should not exceed more than about 50 percent of the current growth before plants go into dormancy.

These measures are based upon the fact that the first principle of grassland management is controlled grazing. The vigor of plants is reduced if they are grazed too young, too frequently or too closely, in which case less palatable plants take their place and thrive because the livestock avoid them; also, moisture retention is lessened and erosion is encouraged as the plant cover thins. Retention of moisture is particularly important where water is a limiting factor in plant growth, as it is over much of the world's grasslands. On heavily grazed pastures, half, or even three quarters, of the water from heavy rains may be lost by run-off as against perhaps only 10 percent when pastures are only lightly grazed. Thus two to three times as much water may go into the soil when the grass is 3 or 4 inches high, as when it is grazed as closely as the animals can bite it off.[8]

Control over the extent, timing, and the kind of grazing is thus of the utmost importance if the original carrying capacity of pastures is not to be lowered. For instance, an experiment in New Mexico aimed at good control of the timing and extent of stocking at different seasons, resulted in the production of 530 kilograms of forage per hectare per year as against 270 kilograms with uncontrolled grazing.[9] Controlled grazing is possible only where there is sufficient fencing, or, if this is not economic, where livestock are effectively herded. Over extensive areas of Latin America, Africa and Australia, more fencing is one of the essential preliminaries to improvement of both livestock and pastures. Another essential preliminary in many areas is a better supply of water, since livestock cannot use grass efficiently unless drinking water is available within easy walking distance. Otherwise, the

[8] A.T. Semple, *Op. cit.*, p. 39.

[9] A.T. Semple, *Op. cit.*, p. 49.

pastures near the watering places are overgrazed, also causing soil erosion, and the remainder is largely wasted. This remains true of large areas in South America, Africa and northern Australia.

Where conditions justify it, controlled grazing may be supplemented by fertilization, water-spreading, or even replacement of indigenous by adapted species by reseeding after plowing. If economical, measures should also include cutting and conservation of fodder and, if possible, production of fodder on arable land, in order to maintain animals on an even plane of nutrition throughout the year and protect the pastures during the critical times of the year and during periods of drought.

It should be noted that while these measures may imply some reduction in rates of stocking for an interim period, regeneration of the pasture, even without improvement, combined with proper management in respect of grazing and cutting, will ultimately make it possible to carry many more livestock than at present without damage to the pastures or the soil.

The scope for pasture improvement is considerably greater where rainfall is higher. Generally speaking, in the more humid regions, the emphasis is not upon regeneration of overgrazed grasslands but on raising the productivity of the pastures by such measures as mowing and controlled rotational grazing, laying down new pastures consisting of more productive and palatable species, often introduced from other countries, top-dressing with fertilizers, including trace elements and/or lime, and integration of pastures with crops as part of an arable rotation.

Particularly great opportunities for increasing pasture productivity, especially in moderate to good rainfall areas, lie in the introduction of grasses and legumes which are superior to the indigenous varieties. For instance, the introduction of lucerne from southern Europe to the pampas of Argentina was one of the principal factors in establishing an economic system of producing great quantities of high-quality beef for export. Likewise, the introduction of such species as subterranean clover from the Mediterranean area to Australia and perennial rye grass from northwest Europe to New Zealand have added greatly to the world's food supply. So far, however, the improved species introduced into Australia and New Zealand have been sown only on a small proportion of the suitable area. " Many important introduc-

tions to Africa, the Americas and Australia indicate the world-wide possibilities of additional discoveries which will increase the productivity of pastures from 50 to 100 percent. At the same time, the native species can, in some cases, be greatly improved by the selection and breeding of improved strains."[10] This last point has been stressed by Myers, who points out that even in the United States, the breeding potentials in the field of grass, where the United States has more than 6,000 species, are almost untouched, compared with the intensive work which has been carried out on many cash crops. " Most of our improved varieties are selections from the wild; few are the result of planned breeding programs. Even our best legumes represent only the first crude screening — at about the same stage as the open-pollinated varieties of corn developed 50 and 100 years ago by mass selection."[11]

As mentioned earlier, use of fertilizers on grasslands is a fairly recent development and its potentialities have been very little realized. Even in Europe, the production of feed from grasslands could be greatly increased by more extensive and effective use of mineral fertilizers. The example of the United Kingdom, where approximately half the area under grass receives no nitrogen, has already been quoted in the section on building up soil fertility. Moderate dressings could add nearly half a million tons of feed in this case. In the United States, Australia and New Zealand, top-dressing of pastures is being increasingly practiced by progressive farmers. In 1952, 58 percent of the fertilizers used in Australia were applied to pastures, compared with 32 percent of a smaller total in 1938.[12] However, the practice has not yet spread to the majority of farms, as is evidenced by the figures quoted in the section on building up soil fertility. Evidence of the usual beneficial effect of top-dressing on yields, provided that moisture is not already the limiting factor in growth, is abundant. For instance, in Louisiana, United States, the yield of native blue-stem pasture was almost doubled and the quality of the variety was markedly improved by the addition of commercial fertilizers. In California, application of nitrogenous and phosphate fertilizers has resulted in increasing forage

[10] A.T. Semple, *Op. cit.*, p. 67.

[11] W.M. Myers, Your greatest opportunity is grass. *Country Gentleman*, August 1952, p. 20, 21, 42 and 43.

[12] Phosphate fertilizers - Australia's needs and supplies. *Quarterly Review of Agricultural Economics*, January 1954.

FIGURE 22. – Swiss alpine pasture.

production two to three times and in doubling the period during which green forage is available for grazing. Fertilizers have proved particularly important in Australia and New Zealand in increasing the productivity of pastures. In Australia, pasture improvement through sowing various grasses and clovers introduced from Europe, along with top-dressing with superphosphate and the addition of lime in wetter districts, frequently raise productivity from the level where several hectares are required to carry 1 sheep to the level of several sheep per hectare. For example, in an experiment in South Australia, the carrying capacity of the pasture was raised approximately from 1 sheep to 10 hectares to 7.5 sheep per hectare as a result of adding superphosphate to a sown pasture. In some cases, the addition of trace elements has multiplied productivity several-fold. Outside the regions and countries mentioned, the use of fertilizers on grass is a thing for the future.

Mowing of pastures is not only a means of conserving surplus growth, which can be kept as hay or silage for feeding to the animals in the seasons when pasture growth is slower or not available, but it is also a means of improving the condition of the pastures. In regions with a strong summer influence, mowing keeps the grass succulent and palatable for a longer period. It also keeps down weeds and less palatable plants, and reduces their competition with the grasses favored by the stock. It has been stated that in the United States livestock production could be profitably doubled on several million hectares along streams and in swales by mowing to keep down weeds and worthless shrubs. In most regions, the spring flush is usually allowed to get away, the grasses becoming coarse and rank in summer, without any attempt being made to improve their composition and maintain their palatability longer, or to conserve the immense quantities of feed which could be obtained by mowing at appropriate intervals during the growing season. The adequate conservation of pasture growth, at a time when it exceeds grazing needs, would represent an addition of many hundreds of millions of tons of fodder throughout the world and increase tremendously the productivity of livestock for draft, milk and meat purposes, as well as avoiding heavy losses during drought periods.

Wherever topography and climate are suited to arable farming, substantial improvement in pasture productivity — not to mention

gains in crop yields — may be obtained by substituting a system of temporary leys, with grass as part of the cropping system, for pure grassland farming. Wahlen has pointed out that "during the war it was demonstrated in Switzerland that former exclusive and very intensively farmed permanent grasslands were capable of maintaining the same livestock numbers if fifteen to twenty-five per cent of the land was used for crop production, because the short-lived artificial leys included in the rotation produced larger quantities of animal food of higher quality." [13] This is a point of considerable significance for northwestern Europe and New Zealand in particular.

Potential carrying capacities

It is, of course, not possible within the limits of our present knowledge, to make anything approaching a precise estimate of the potential carrying capacity of cattle and sheep for the world as a whole. However, our knowledge of the possibilities of pasture improvement and management, along with estimates of livestock potentials for a few countries, does indicate that in many regions the potential for livestock numbers is far above the present population. For instance, a recent study for the United States bears eloquent testimony to the immense possibilities for increasing the production of livestock products without competing for the use of the arable land. The former director of field crops research in the United States Department of Agriculture estimates that the grasslands of the western United States could be developed to carry 50 percent more cattle and sheep, that the carrying capacity in the northeast could be increased 140 percent and in the southeast 375 percent. The potential for dairy herds, on the basis of present knowledge of pasture improvement, is estimated at 84 million, compared with present numbers of 46 million; of beef herds at 130 million against 50 million now; and of sheep at 60 million against 31 million at present. [14] If these figures are translated into livestock units, they place the United States potential at about two and a half times present numbers.

In Australia, Davies considers that improvement of the pastures in what are now good rainfall grazing areas in New South Wales and

[13] F.T. Wahlen, *Op. cit.*, p. 12-13.
[14] W.M. Myers, *Op. cit.*

Victoria alone would make it possible to carry as a very minimum 164 million sheep in these states as against 70 million carried at the date of writing. In 1957-59, numbers had already risen to 101 million; and in Queensland it would raise the carrying capacity for cattle from 6 to around 19 million.[15] Full development of pastures, integration of crop and livestock farming on the much greater area than is capable of being brought under an arable rotation, and development of the northern areas would certainly make possible livestock numbers not less than four times present populations, with a considerably higher percentage increase in cattle than sheep. The eventual figure might be much higher than this.

Information on Latin America is quite inadequate for any such over-all estimate. In particular, we know very little about the measures through which it will be possible to develop the undoubtedly tremendous potentials of the vast savannas. It is unlikely, however, that the potential increase in livestock numbers is of a lower order than in the United States.

In Africa, there is ample evidence of overstocking of pastures with resultant soil erosion, but there is also ample evidence that with proper pasture management double the number of livestock could be carried on these pastures at a high level of nutrition. There are also large areas now excluded entirely from animal production by the tsetse fly. The potential in Africa is tremendous when this menace is controlled and sound pasture management methods put into effect, including substitution of better grasses where these can be found. Overgrazing is also frequently stated to be a limiting factor in the Near East, and it is often advocated that livestock numbers should be reduced. But in this region, in particular, where the sedentary farmer and the nomad have always belonged to two different economic systems and two different ways of life, the development of an integrated livestock cropping system in the more humid areas and proper pasture management would allow for a big increase in animal numbers, as well as an increase in crop production for human consumption.

In the Far East, the situation is somewhat different, in that excess numbers of cattle in India have led to virtual stagnation of the cattle

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[15] J. Griffith Davies, Pastures in the Australian economy. *Journal of the Australian Institute of Agricultural Science*, Vol. 18, June 1952.

industry. Even with the best possible utilization of feed resources, India has nearly one quarter of the cattle population of the world and large numbers are virtually nonproductive, being too small for draft power and of no practical value for milk production. On the other hand, there is a shortage of good animals for both draft power and milk. Basic changes in livestock policy, which must depend upon changes in public opinion, are necessary in order to remove many millions of economically useless animals, replacing these to the extent necessary with productive animals, practice improved systems of livestock management and feeding and, in particular, integrate livestock production with cropping. Elsewhere in the region, there are substantial possibilities for increasing the number of grazing animals, and especially in China, which possesses extensive areas of excellent but little utilized pastures in the southwest. However, in view of the tremendous number of cattle in India, which are quite unable to be maintained adequately by feed resources as utilized at present, the potential for increase in total numbers in the region as a whole would probably be modest. In this region, the important thing is to upgrade, feed properly and care better for existing numbers, in order to raise productivity per animal. Achievement of reasonable levels of productivity would in itself afford an increase in output of about five times both in the case of sheep and cattle. Greatly increased numbers of pigs and poultry would, of course, be possible.

In Europe also, the potential for increased numbers is modest compared with the Americas, Oceania and Africa. However, there is still scope for greatly increasing the productivity of a large proportion of the area under grass, while increased crop yields both of animal feedstuffs and crops for direct human consumption could augment the supplementary feed supply, partly through devoting a higher proportion of the arable land to production of feed grains and roots. Considering the world as a whole, one can say that the potential feed basis exists for a very substantial increase in cattle and sheep numbers. Information for most regions is too limited to make possible even an approximate estimate, but it would seem conservative to estimate a doubling of present numbers if one assumes (*a*) that the study of tropical and subtropical pastures is brought to the same level as that of the temperate grasses; (*b*) general application by farmers of present knowledge on improvement and maintenance of pastures;

(*c*) higher crop yields, making possible substantial increases in production of coarse grains and forage crops, partly through diversion of area to these crops.

In conclusion, taking into account both the potential feed base for higher livestock populations and the scope for increased production per animal, and assuming in respect of the latter a general level of achievement equal to the present performance of the average farmer in the better but not necessarily the best countries, it can be seen that the resource and technical basis exist for a level of production of livestock products of certainly not less than five times the present world output. Naturally, heavy investments in research, extension and capital expenditures would be required. The rate at which these goals might be approached, given various assumptions in regard to investments, training of personnel, research, and overcoming adverse institutional conditions, would constitute another and more difficult study.

5. POSSIBILITIES OF INCREASING THE CONTRIBUTION OF FISHERIES TO WORLD FOOD SUPPLIES

General information

Although fisheries are usually associated with agriculture and considered as part of the general problem of rural development, there are some considerations which distinguish fisheries very markedly from agriculture:

1. In developed and underdeveloped countries alike, the fisheries are, in most cases, of relatively small economic importance and involve only small sectors of the population.
2. In the underdeveloped countries, increased fish production largely involves the exploitation or creation of additional resources, e.g., by taking fish which are already there — a gift of nature — but for various reasons are not being taken now, or which could be introduced and reared in bodies of water not previously utilized.
3. A large part of the sea's fishing grounds lies beyond national boundaries and, in these days of factory ships and large fishing vessels, may be exploited by virtually any country from any distance.

Against this background, the volume of fish production is fairly impressive, but even more impressive is the rate of increase which may be achieved in certain circumstances. While this is not to say that the same rate of increase could be maintained indefinitely, it does indicate that in purely physical terms there are opportunities for a very rapid increase of fish production up to a certain level in certain places, by harvesting stocks which can be fairly readily located or cultivated. This has been shown to be true even without any change in traditional techniques and is illustrated by local increases which reflect greater demand or, quite simply, the natural increase in the number of fishermen. In many places, the process could be, and has been, greatly accelerated by the application of modern technology.

World fish production and trade

Tables 4 and 5 show, in round figures, the volume and location of world fish production and trade, and rough figures for cattle meat production and trade are given by way of comparison with a more familiar commodity.

Table 4. – World fish production and trade, with comparative figures for meat

A. Production

Region	Fish			Beef and veal
	1950-52	1959	1961	1960
	Thousand metric tons			
Africa	1 280	2 230	2 470	1 600
North America	3 480	3 990	3 950	7 800
Latin America	640	3 190	6 520	5 200
Asia	8 530	15 380	16 690	[1]2 900
Europe	6 640	8 070	8 160	6 300
Oceania	90	120	120	900
U.S.S.R.	1 830	2 760	3 250	[2]3 200
Near East	—	—	—	700
Total	22 490	35 740	41 160	28 600

[1] 1958. — [2] 1959.

B. Trade (exports)

Commodity	1948	1959	1961
	Thousand metric tons product weight		
Fish: fresh, frozen, dried, salted, smoked and canned, fish meals and fish oils	1 700	3 700	4 300
Fresh meat and prepared and canned meats	[1]2 200	4 300	—

[1] Average 1948-52.

Table 5. – Examples of rapid increases in fish production

Country	1920	1938	1947	1959	1961
	Thousand metric tons live weight				
Japan	2 300	3 500	2 200	5 900	6 700
Denmark and Faeroe Islands	92	160	300	760	760
South Africa and South West Africa	—	67	120	740	1 010
Peru	—	—	30	2 150	5 200
India	—	—	[2]530	820	—
Chile	11	32	61	270	430
Poland	[1]1	13	40	160	190

[1] 1921. — [2] 1945.

Opportunities for expansion

More than 75 percent of the earth's surface is covered by water from which, however, only 10 percent of animal protein and not more than about 1 percent of total food supplies are derived.

On the basis of existing knowledge of known fishery resources, the FAO Conference, at its sixth session, recorded its view that world fish production could be doubled without detriment to these resources.

Leading scientific opinion indicates that the primary production of the sea is about equal to that of the land, and that the primary production of all waters, therefore, must exceed that of the land.

Exploitation of aquatic resources has been mainly concerned so far with the taking of fish, i.e., animal protein, and has been measured to a great extent by the availability and price of other competing protein foods.

Increased pressure on the land and the cost of exploiting new agricultural resources may shift the balance of advantage in favor of fisheries — in the first instance to achieve fuller utilization of protein supplies from the waters and eventually perhaps to exploit their vegetation.

Although in the present state of our knowledge it is not possible to make quantitative estimates concerning wild stocks, enough is known to indicate certain resources which appear capable of more extensive exploitation, granted the essential favorable economic and social circumstances.

Marine resources

Fish

It is always difficult to forecast potential yields from large oceanic areas, of which modern research has touched only a small part. From the standpoint of food production, there is the twofold problem here of safeguarding those stocks already intensively fished which are of well-established economic and nutritional importance, and that of extending the area of exploitation as well as making better use of species not yet fully exploited commercially. With regard to area, it must be remembered that the bulk of fishing takes place on continental shelves which form only about 10 percent of the total marine area and that

possibilities of exploiting deeper waters with the aid of modern technology are becoming a matter of increasing interest and concern among the fishing countries.

With regard to species, there are a number which are only partially exploited at present but which it is believed could support much larger fisheries. Examples are the mackerels and sardine-like fishes and related species in the Arabian Sea and Persian Gulf, hake of the Patagonian shelf, and a large group of perch-like species which are of particular importance in tropical regions. The occurrence of the latter in waters overlying coral and other reefy ground directs attention to the very large stretches of such reefs in northern Australian waters, Indonesian and Philippine waters, the South China Sea, off the African coast and in the Caribbean. It is also widely held that the tunas could be taken in greater quantities in the central and northern Pacific, the waters around the Philippines and Indonesian archipelagos, in the northern Indian Ocean, and in the south and equatorial Atlantic.

Finally, an important section of total fish production consists of crustaceans and mollusks. Although not enough is known about the existence of natural stocks not already exploited, there are certainly very extensive areas of foreshore in the world along which cultivation can be undertaken. Although fishing is one of the most ancient of man's occupations, entirely new resources of crustaceans have been located and exploited even as recently as the present century, i.e., off the eastern coasts of America and Australia and in the Gulf of Mexico. On the evidence of past experience, there would certainly appear to be a strong case for investigation of the areas of the Bay of Bengal off the mouths of the Ganges and the Godavari and other great rivers, and of similar areas off the mouths of the great rivers of New Guinea and Borneo. Japan, for example, takes about a million tons annually of crustaceans and mollusks, and the United States over 800,000 tons.

Seaweed

Experts estimate that there are at least 60 million tons of seaweed growing on the coasts of Norway, France, the British Isles, Canada, the United States and the Falkland Islands. Apart from a few thousand tons taken by Norway and Canada, these resources are practically

untouched. An outstanding example of the valuable uses to which seaweed can be put, including a wide range of food and chemical products, is to be found in Japan, where in some years the annual harvest has exceeded 500,000 tons.

Zooplankton

The total volume of zooplankton in the world's waters has not yet been estimated, but as an example, the standing crop of zooplankton in the Antarctic is perhaps of the order of tens of millions of tons. Although at the present time the exploitation of such resources is not technically or economically feasible in many places, it must be borne in mind that very considerable quantities of zooplankton are used in Asian countries for the manufacture of pastes and other fishery products, and that interest in overcoming the technical problems is growing.

Inland waters

It is perhaps not sufficiently appreciated generally that inland waters yield over 5 million tons of fish annually, i.e., about 15 percent of total world fish supplies. Most of this production is drawn from:

(*a*) subsistence fishing of wild stocks in the lakes and rivers of the Asian continent and of Latin America;

(*b*) commercial fishing in the Great Lakes of Canada and the United States, East Africa, China and Cambodia, and from the river systems of Europe and other continents;

(*c*) fish culture in the freshwater areas of China, India and Japan and in the brackish waters of Taiwan, the Philippines and Indonesia.

A notable section of the freshwater production is from wet rice paddy fields, of which there are millions of hectares in southeast Asia and the Far East. Great increases of production could be achieved by better management of the inland waters, including the control of fishing, improvement of waterways, protection of migratory paths, and similar measures. Fish culture could provide great increases in bodies of impounded waters ranging from small domestic ponds and tanks to large reservoirs, of which the number is increasing regularly with the progress of large irrigation projects. There are many areas of swampy, brackish, foreshore waters which might be

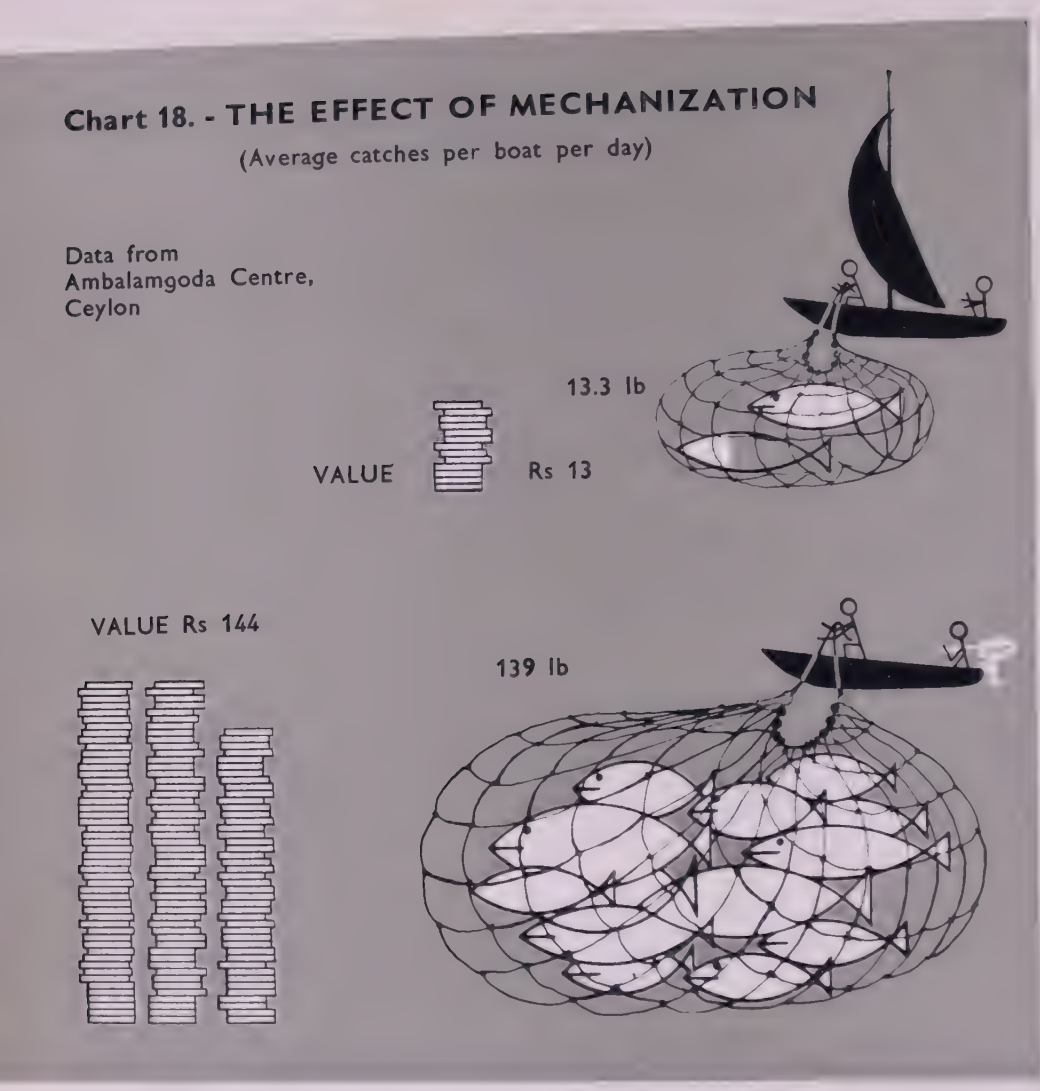
used for cultivation after the manner practiced in Indonesia and the Philippines. Altogether in the Indo-Pacific area alone, it has been estimated that the area of inland waters which can be used for fish culture is 37 million hectares.

Methods of realizing the opportunities for expansion

From the foregoing, it will be evident that in contrast to agriculture, the seas and inland waters provide many opportunities for increasing fish production, merely by increasing the fishing effort, with or without changes of traditional techniques. This throws very great emphasis on the demand factor and with it the incentive for the fishermen to catch more fish. If, as a result of nutritional education or other measures, more people can be persuaded to want to buy fish, and if the means can be found to get fish from the beaches where they are landed to the people at prices comparable with the prices of alternative types of protein food, the fishing effort can be fairly easily and quickly increased far above present levels. It is in this context that the various methods of achieving high levels of fish production are described and exemplified below.

Improvement of fishing methods

There are very few statistics available concerning the efficiency of the different methods used in fishing and, allowing for the fact that some traditional techniques may be extremely well adapted to the environment in which they are used, it is quite evident that the productivity of the many thousands of fishermen in the Indo-Pacific region, in Africa and in Latin America is very low compared with that of their counterparts in the modern industries of North America and Europe. Comparisons require considerable qualification by reference to natural and economic factors locally, but there is certainly a challenge in the fact that in a very large number of underdeveloped fisheries, a fisherman catches not much more and sometimes less than 1 ton of fish per year, whereas his counterpart's share in an Arctic trawler will often be as much as that in two days. Whatever quantitative estimates may be lacking, it is immediately obvious that if the incentive and the demand were there, the efficiency of fishing opera-



tions in the underdeveloped areas could be very readily increased by the adaptation and use of fishing vessels and gear already used widely in other fisheries, including many of great simplicity compared with the complexity of ancient traditional methods. For example, simple outboard engines have been introduced in hundreds of fishing boats in Chile, the Federation of Malaya, Jamaica, Senegal, Ceylon and elsewhere. In Puerto Rico, it is estimated that fishermen have increased their catches by 50 percent and their incomes proportionately more by the installation of simple outboard and inboard motors. Increased catches by mechanized boats amounting to anything from double to

ten times the catches of traditional craft have been reported from Bombay and Ceylon.

FAO is actively engaged in this field and has been promoting the mechanization of fishing craft in India, Ceylon, Ecuador and other countries. The progressive improvement in the design and efficiency of fishing vessels has been a conspicuous feature of the modern fishing industries in Europe, North America and Japan. Some experts have estimated that improvements in the design of modern trawlers in northern Europe have reduced fuel consumption by as much as 30 percent, to say nothing of additional advantages in the fishing operations themselves. Although in the underdeveloped fisheries generally much reliance will continue to be placed on quite small fishing units, there are plenty of examples now of the successful introduction of larger units capable of fishing over much greater distances. Judged purely from the standpoint of food production, these measures can be regarded as examples of the exploitation of fishing grounds not previously used by the countries concerned. Thus modern trawlers, purse-seiners, etc., have been introduced in certain places in India, Ceylon, West Africa and Latin America. The very rapid postwar expansion of fisheries in Chile, Peru and South Africa has been based on the introduction of such modern units. Improvements in fishing gear alone have also been responsible for rapid increases in production. Similarly, aids to navigation and electronic instruments for the detection of fish have greatly facilitated the most difficult operation of locating fish stocks. The possible extension of the use of electricity for attracting and surrounding fish must not be overlooked, in view of its successful use in inland waters. Much of the equipment and gear used in modern fishing industries is virtually unknown in large areas of the underdeveloped fisheries.

Improving the preparation and utilization of fish products

One of the most obvious and most practical ways of increasing the world's food supplies from the fisheries is by improvements in preparation and utilization which (*a*) make use of less popular or rejected species caught incidentally with other species, as also of those parts of the fish now wasted during handling and processing; and (*b*) prevent or reduce the spoilage of fish during the time between

FIGURE 23. – Ceylon: a traditional catamaran fitted with an outboard motor. Mechanization increases yields tenfold.

FIGURE 24. – A 7.5-meter mechanized fishing boat, designed by an FAO expert for quantity production in Ceylon.

landing and consumption. In this connection, it must be noted that the development of the great fishery industries of North America, Europe and Japan rests as much on the facilities for marketing and distribution in these areas as on the highly efficient techniques employed in fishing. It is almost impossible to overemphasize the importance of the problem represented by the extreme perishability of fish in its fresh state. In large areas of the world, where food supplies are most critical, especially protein food supplies, and where high hopes are attached to the development of fishery industries, there are large sectors of the population to whom fish simply is not available, or at least only rarely available, because satisfactory arrangements do not exist for the treatment, storage and distribution of fish products in an edible condition. This is particularly the case in hot countries. For example, in India, about one half and in Pakistan about three quarters of fish supplies are consumed fresh, which means a very limited area of distribution, mainly among coastal communities. The remainder is processed in some form, usually dried, while significant quantities are wasted from time to time and in particular localities. Considerable spoilage occurs even among that proportion which is processed for distribution over larger areas. Clearly, therefore, any measures which would eliminate such wastage and permit distribution over a wider consuming area could have the immediate effect of making fish available to more people as well as that of increasing the incentive to catch more fish. Prominent among such measures are those which reduce the period and extent of exposure to contamination during processing and distribution. Over large areas of tropical and subtropical continents, fish is mainly processed by simply exposing it to the sun and by smoking it over open wood fires. In Africa, these methods are particularly widespread, and FAO has demonstrated the possibility of reducing the period of treatment from ten to less than two days, with greatly reduced exposure to infestation. There are no statistics to permit estimates of the quantities of fish lost through infestation and spoilage during storage and transport but there is general agreement among very many observers that these are very considerable. Measures to counteract such spoilage through more efficient storage and transport can significantly increase the volume of supplies available for consumption.

The importance of processing, by freezing, curing, canning or reduction, in the most highly developed fishing countries, may be

measured by the fact that in Canada over 80 percent, in the United States over 70 percent, in Norway nearly 90 percent and in Japan over 70 percent of the catches are processed in one of these forms. In this connection, some reference must be made to the very large quantities of fish now processed into fish meal for incorporation in animal feeding stuffs — nearly 5 million tons of fish annually. In the first place, it is important because this form of utilization permitted the expansion of the Norwegian winter *herring* fishery from about 500,000 tons in 1945 to over 1 million tons annually in the 1950s; the United States production of *menhaden* from about 350,000 tons in 1945 to nearly 1 million tons in 1959; the production of *pilchards* in South Africa and South West Africa from negligible quantities to over 400,000 tons annually; the production of *anchovies* in Peru from less than 50,000 tons annually in 1953 to over 5 million tons in 1961, with lesser but very significant increases in Denmark and Chile. Secondly, there is considerable speculation as to the prospect for adapting this form of fish product for human consumption and the various experiments with which FAO is at present associated, particularly in Africa, throw emphasis on the problems of consumer preferences which in many parts of the world limit the market for existing fish supplies and restrain fish production below levels which would be technically feasible. In some countries, there are religious sanctions against consumption, either of fish in general or of certain kinds of fish, e.g., scaleless fish; in some, the communities accustomed to eating freshwater fish will not accept marine fishes, and vice versa; in very many countries, people do not eat fish simply because it is unfamiliar and has never been readily available to them. However, it has been demonstrated, e.g., in Chile, Mexico and Yugoslavia, that a well-organized and sustained program of consumer education can overcome prejudice, especially through schoolchildren. These measures are of special importance in countries where protein malnutrition is prevalent and where fish could be cheaper or more readily available than meat. In the commercial field, advertising has played a very large part in popularizing the consumption of canned and frozen fish in North America and Europe. In the majority of underdeveloped fisheries, the reform and reorganization of marketing arrangements and facilities and the improvement of the technical processes and methods involved must accompany measures to increase production if the products of the seas and inland

FIGURE 25. – A freshwater fish experimental station in Indonesia: breeding stock about to be transferred to other ponds.

FIGURE 26. – Sun-drying salt fish in India. This method results in an unpalatable and nutritionally inferior product.

waters are to make their most effective contribution to the relief of food shortages. Their importance must be measured in terms of the large quantities now wasted after catching, as also by the additional quantities which could be taken if the channels of distribution were less restricted than they are now in many parts of the world, especially Asia and the Far East and Africa, where fish is often the main source of animal protein.

Improving public and private organization for fishery development

Even where the opportunities for, and the methods of, development are well known and understood, and even when financial resources are available, there are still great obstacles to further progress, represented by the low levels of education and lack of understanding and incentives among the many thousands of small fishermen and traders in the more backward fisheries, in the absence of adequate commercial structures for handling and marketing larger quantities of fish products, the great scarcity of technical personnel capable of operating modern plants and equipment, and the inexperience of governments themselves when dealing with the fishery industries for the first time. The problems are both national and international in scope.

National

In the more highly developed fishing countries, which by and large are self-sufficient commercially, there are still many problems requiring attention and in particular the help of governments, if more effective exploitation of the fishery resources is to be achieved. Apart from the fairly obvious requirements for public assistance in economic, technological and biological research, and in the more advanced vocational training consistent with modern technology, there are also more complex problems concerned, for example, with marketing, including especially the precarious level of demand and even decline of fish consumption in some countries and also concerning the financing and development of less progressive sectors, especially among the widespread inshore fisheries. A large part of the construction of the fishing fleets since the second world war, especially of the smaller and medium-sized fishing vessels, has been made possible only with the

FIGURE 27. – Field drier designed by an FAO expert at Lake Edward, Uganda. It can deal with about 270 kilograms of fish at each operation (24-36 hours).

help of special credit facilities provided by governments. A number of special development authorities and boards have been set up under public supervision or control for the purpose of consolidating or developing the fishery industries, e.g., in Canada, the United Kingdom, the Netherlands and South Africa. In the underdeveloped fisheries, the need for such assistance is very much greater and ranges from the earliest planning stages of fishery programs through all stages of their implementation. Well-planned government help has been and is expected to remain for a long time the basis for the development of these more backward fishery industries and the fuller exploitation of the resources to which they have access. In most of these countries, development has been characterized by the provision from public funds of improved fishing boats and gear, harbor facilities, storage, processing, transport and marketing facilities, experimental and exploratory fishing voyages, and the services of trained personnel not available within the fishery industries themselves. A good deal of FAO's work has been mainly in this field, directed to the planning and execution of fishery development programs.

In the context of this study, it need only be noted that in relation to the prospects for increased fish production and consumption, represented by the resources not yet brought under effective exploitation, and the manifest needs for larger supplies of protein among large populations of southeast Asia and the Far East, Africa and Latin America, the available resources of funds and personnel are sufficient only to make very modest beginnings in certain localities.

International

In the broader context of potential fish supplies in relation to over-all world food supplies and needs, the one overriding consideration is that the greater part and the most productive of the sea's fishing grounds are not contained within national boundaries and are subject to exploitation by more than one country from virtually any distance.

To what extent and in what manner the resources of the sea will in the future be exploited so as to make their most effective contribution to the resolution of world food problems will depend in very large measure on the willingness of governments to make available

TABLE 6. – AREA OF CULTIVABLE INLAND WATERS IN THE INDO-PACIFIC REGION [1]

Country	Fish ponds		Natural lakes	Artificial lakes, reservoirs, tanks	Salt or mangrove swamps suitable for fish culture	Lagoons, estuaries, suitable for fish culture	Wet rice fields		Total inland waters	Area of arable land	Total area of country	Percentage of inland water to total area of country
	Freshwater	Brackish water					Without fish culture	With fish culture				
	Thousand hectares											
Burma	—	—	...	...	...	...	510	—	...	8 754	...	...
Cambodia	120	—	350	1	...	72	1 400	—	...	...	...	...
Ceylon	—	—	—	8	—	117	350	—	547	1 469	6 600	8.29
Fed. of Malaya	ø	—	...	1	300	—	315	46	661	2 129	13 530	4.88
Hawaii	—	1	—	...	—	...	...	...	...	...	...	...
Hong Kong	ø	ø	—	ø	1	6	8	ø	...	13	101	15.58
India	338	3	726	180	121	264	5 763	2	7 396	123 820	316 100	2.34
Indonesia	9	110	335	27	6 000	8 500	4 500	67	19 548	11 000	149 200	13.10
Japan	1	—	21	...	...	...	2 991	9	3 021	5 992	38 200	7.90
Korea, South	...	...	...	...	...	...	1 226	—	...	1 954	...	...
Laos	...	...	...	...	...	...	...	...	...	...	...	...
New Guinea (Australian)	—	—	80	—	500	100	—	—	...	...	...	...
North Borneo	—	—	—	ø	195	...	18	—	213	...	19 100	1.11
Pakistan	105	25	30	69	305	424	43	12	1 013	21 000	94 300	1.18
Philippines	ø	85	...	230	...	500	...	...	...	...	29 741	...
Singapore	...	ø	—	—	—	—	—	—	ø	...	70	0.36
Taiwan	10	113	2	10	...	...	520	8	...	...	...	...
Thailand	ø	...	26	...	...	...	...	...	6 161	4 751	50 000	12.37
Viet-Nam	25	2	3	2	14	54	4 068	2	4 170	3 200	32 800	12.71
West New Guinea (West Irian)	—	—	82	—	...	...	—	—	...	10	40 000	...

[1] Prepared by W.H. Schuster on the basis of the *Handbook of Fish Culture in the Indo-Pacific Region* by S.L. Hora. FAO, Rome. 1955. 264 p.

ø Less than half the unit used.
... Information not available.

the necessary resources of funds and skills and to co-operate in joint action for the wise management of the sea's resources, and in measures to improve the flow of fish supplies to the areas where they are most needed. This is a major challenge, and although a few first steps have been taken, there is still a great deal to be done before even rough estimates can be formed as to the volume, composition and behavior of the fish resources of the seas. A very great deal more must be accomplished before international management and utilization of the resources can be foreseen.

At the national level, much is being accomplished from the standpoint of exploiting and measuring these resources, but the point is being reached where not only could this work be much more rapidly advanced by appropriate international collaboration but is in danger of being frustrated for want of the latter.

In the following areas, international councils and commissions have already been set up: Northwest Atlantic, Northeast Atlantic, Mediterranean, North Pacific, East Tropical Pacific, seas bordering Latin America, all oceans for whaling.

Similar bodies have been sponsored by FAO in the Far East and southeast Asia, the Mediterranean, West Africa and the eastern part of Latin America, e.g., the Indo-Pacific Fisheries Council, the General Fisheries Council for the Mediterranean, the West African Fisheries Advisory Commission and the South West Atlantic Fisheries Advisory Commission. These bodies have contributed much to the assembly and interpretation of scientific information concerning the resources, and to the promotion of co-operative research programs. They and FAO have done much to focus world attention on the problems arising from the exploitation of the same fishing grounds by different nations and, in some cases, agreement has been reached on measures for better management.

However, as has been said above, the future of the world's sea fisheries will depend on much more comprehensive, vigorous and harmonious international action, in order to promote the appropriate forms of management by which wastage of costly skills and equipment can be avoided and the yields from resources of economic and nutritional importance can be improved, and eventually, perhaps, to achieve some form of husbandry through which the resources of the sea can best be used to supply human needs.

6. POSSIBILITIES OF INCREASING THE DEVELOPMENT OF FOREST RESOURCES

Generally speaking, the production of the forest products required by rising generations of men whose needs are likely to be larger than those of their predecessors is far from implying a sacrifice in terms of farm production. On the contrary, forests are a necessity in a sound comprehensive land-use policy, not only in order to provide wood and other products but also to safeguard the food potential of the land itself and to increase its yields. But the mere existence of a certain area of forests is not enough: just as every square meter of agricultural land must be made to produce as much food as possible, so every tract of forest land must be managed for the most desirable combination of productive and protective functions.

Present use of forest resources

Almost 30 percent of the world's land area, or about 4,400 million hectares, are covered by forests: but only one third of this forest area is in use, and more than another third is at present considered inaccessible. The world's forests are theoretically capable of providing for the needs of a population much higher than that of today. But forest areas are very unevenly distributed throughout the world. Nearly one half of the world's forests are concentrated in the U.S.S.R. and South America, where extensive areas of virgin forests still exist, while in other continents existing stands are severely overexploited or destroyed for timber extraction, shifting cultivation, livestock grazing and by fire.

Only about 40 percent of the forests in use are managed with a working plan: this means that cutting practices are to some degree destructive in 60 percent of the world's forests. However, even with management plans, the need for wood causes excessive fellings in

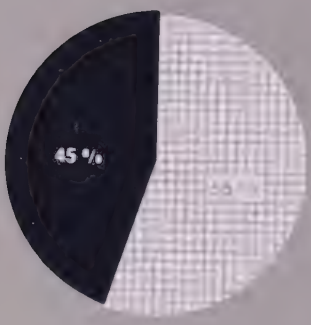
Chart 19. - REGIONAL BREAKDOWN OF TOTAL FOREST AREA

U.S.S.R.

Inaccessible

Accessible - not in use

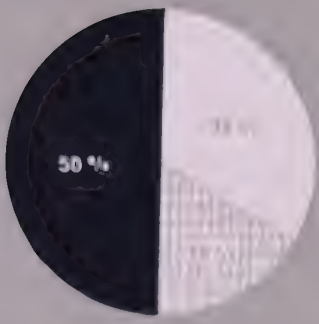
Accessible - in use



NORTH AMERICA

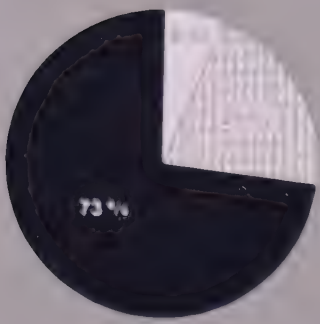
ASIA

EUROPE



AFRICA

LATIN AMERICA



OCEANIA

timber-deficit areas: in Europe, for instance, although 97 percent of all forests in use are under a working plan, fellings exceed the maximum allowable cut. Nevertheless, for the world as a whole, this picture no longer holds true: total fellings at 1,700 million cubic meters are only slightly more than half the estimated gross increment of the world's forests. Although this over-all figure conceals considerable differences from region to region, it may be taken as an indication of the existing potential in the world's forests.

Furthermore, the present increment of existing forests gives no clear picture of their production potential. There are many ways of increasing productivity per hectare over vast areas of virgin forests or badly managed forests.

Increase in the forest potential

The main forest problem consists partly in raising forest yields to the highest possible level and partly in growing forest within easy reach of the people who need wood or timber. Wood and timber are cumbersome commodities which cannot bear long-distance transportation. Now, it so happens that the large concentrations of population have left very little or no forest around them in their search for agricultural lands, even when, as a result of the forest clearing, erosion was accelerated or the water regimen disturbed.

The only solution of the second part of this problem is afforestation, which at the same time will also control erosion and run-off, where it is possible.

Raising of forest yields can only be done through various improvements resulting from an intensified silvicultural treatment of the forests which may require substantial expenditure. In the Far East, the present increment in the forests in use has been estimated at 50 million cubic meters for conifers, equivalent to 2 cubic meters per hectare, and at 160 million cubic meters, or 0.8 cubic meter per hectare, for broadleaved species. There is no reason why the coniferous increment should not be developed and the increment of broadleaved species trebled. Even in Europe, the average yield of the forests is at present around 2 cubic meters per hectare. If it were possible to raise gradually Europe's average yields to as much as 5 cubic meters,

FIGURE 28. – Training forest workers. Better forest practices bring higher yields.

this should permit annual fellings sufficient to cover increases in requirements for at least another century ahead.

Some of these silvicultural improvements would also help to increase wood supplies during the coming decade. In addition, however, the immediate deficit will have to be met by drawing on various reserves which exist in many areas of the world.

Improved management of forests in use

Much can be done to make better use of the supply potential of the existing forests. In the first place, there is the possibility of less selective exploitation of the forests already in use. This involves finding markets for the hitherto unmerchantable species and sizes, either as general-purpose sawn timber, or as raw material for products such as pulp or particle board. For instance, for the Far East, it is probably true to say that complete utilization on the above lines would nearly double production, but the extent to which such an increase can be achieved depends on the solution of problems which are partly technical and partly economic. The same applies to West Africa, where altogether some 40 tree species are exported, although only 15 of these are subject to any considerable regular demand. All of them constitute but a small part of the world's forest resources.

Exploitation of inaccessible forests

Perhaps the greatest increase in production can be achieved by bringing hitherto unexploited forests into use. At present only 1,500 million hectares are utilized in the world. Even allowing for the fact that many of the unexploited forests are of relatively poor quality, there are known to be very large areas of rich forest, for example, on the West African coast and in southeast Asia. Most of these areas are remote from centers of consumption and difficulties of transport may be great, but in the long run, these difficulties should not be unsurmountable. In many cases, the long-term solution will lie in opening up the areas for general development as part of a solution to the problem of finding room for the rapidly expanding populations. This will involve clearing of forests, but there is no harm in this if it is properly planned, so that erosion and other damage do not re-

FIGURE 29. – Improved transport methods, building of forest roads, etc., bring into production hitherto inaccessible forests.

sult, and if forest industries are developed at the same time. A yield of only 1 cubic meter per hectare per annum from only half of the 2,900 million hectares at present unused would result in an enormous increase in production — about double the present world production; the initial yield in many virgin forests, especially in some large areas of tropical Africa and Asia, may in fact be much larger.

Wood from trees outside the forest

During the present century, it has been recognized that individual trees or groups of trees can exercise various beneficial influences, and more recently large windbreak and shelterbelt plantations have been undertaken to improve climate and soil fertility. In some heavily populated areas in the world as, for instance, the Ganges plain in India, where the planting of forests is often quite impracticable, villagers should be persuaded to grow a few trees on the boundaries of the fields and on farmland. Tree growth, in these cases, should be primarily for production of fuelwood, but by taking care of the larger trees, these plantations could also become sources of industrial wood. Sometimes, indeed, trees are planted on agricultural land for this purpose; many farmers have a small plantation of poplars or eucalyptus, perhaps ⅓ to 1 hectare, hoping in this way to obtain an increased income from the land.

Moreover, with the introduction of community centers and extension services, vast lands could be converted into village forests through the co-operative efforts of the community itself.

Afforestation of new areas

It has been explained why, despite the apparent abundance of forests in the world, afforestation is necessary. Many countries have plans, whether explicitly formulated or not, for the development of their forest areas. This may either take the form of new plantings on areas which are now barren or in farm use, or of the enrichment of areas which are now technically classed as forests but whose output, especially of industrial wood, is low. Such schemes of development have as their chief aims the protection of the soil through the checking of erosion and the location of timber production within reachable dis-

tance of consuming centers. In some densely populated countries, plans for afforestation come up against strong competition from farmers and grazers, particularly in the Mediterranean region, where there are vast areas on which neither crops nor livestock can be raised economically. While in this area afforestation is necessary, both for erosion control and for wood and timber supply for the population, as well as for industrial development, in Europe, the main reason is the establishment of forest stands for raising timber production, the consumption of which is rapidly increasing. The available land area for plantation in this continent is evaluated at 7 to 9 million hectares, a relatively high figure, which is explained by the fact that many lands marginal for agriculture have been abandoned, due to the attraction of people to industrial towns. It is obvious that a similar evolution will take place in the other parts of the world but this time has not yet come. However, in the Far East, as annual yields of 10 to 20 cubic meters per hectare are obtainable on moderately good land, plantations covering an area equal to only 5 percent of the existing forests in use, that is, about 10 million hectares, should be capable of producing about 150 million cubic meters, or nearly twice the present production of industrial wood in the region. Plantations are particularly indicated where forests are scarce and for the production of long-fibered groundwood pulp, as there is a great deficiency of suitable raw material for this purpose in the region.

Better utilization of the forest crop

A large portion of the wood that is cut in the forest is never put to any use, and more is lost between industry and the final consumer. Much has been done in the past 40 years to reduce losses in the course of forest operations, to direct fuelwood to industrial uses, to use sawmill waste in pulp manufacture, and in other ways to make fuller use of the roundwood available. Yet what may be called the "net industrial utilization" of the total wood supply remains rather low. Even in Sweden, well over half of the total volume of roundwood used for making sawn timber and pulp is accounted for by various kinds of losses and wastage, and in almost every other country losses are still greater. In the Philippines, the volume of forest resources lost through fire and shifting cultivation — 6 million cubic meters — is higher

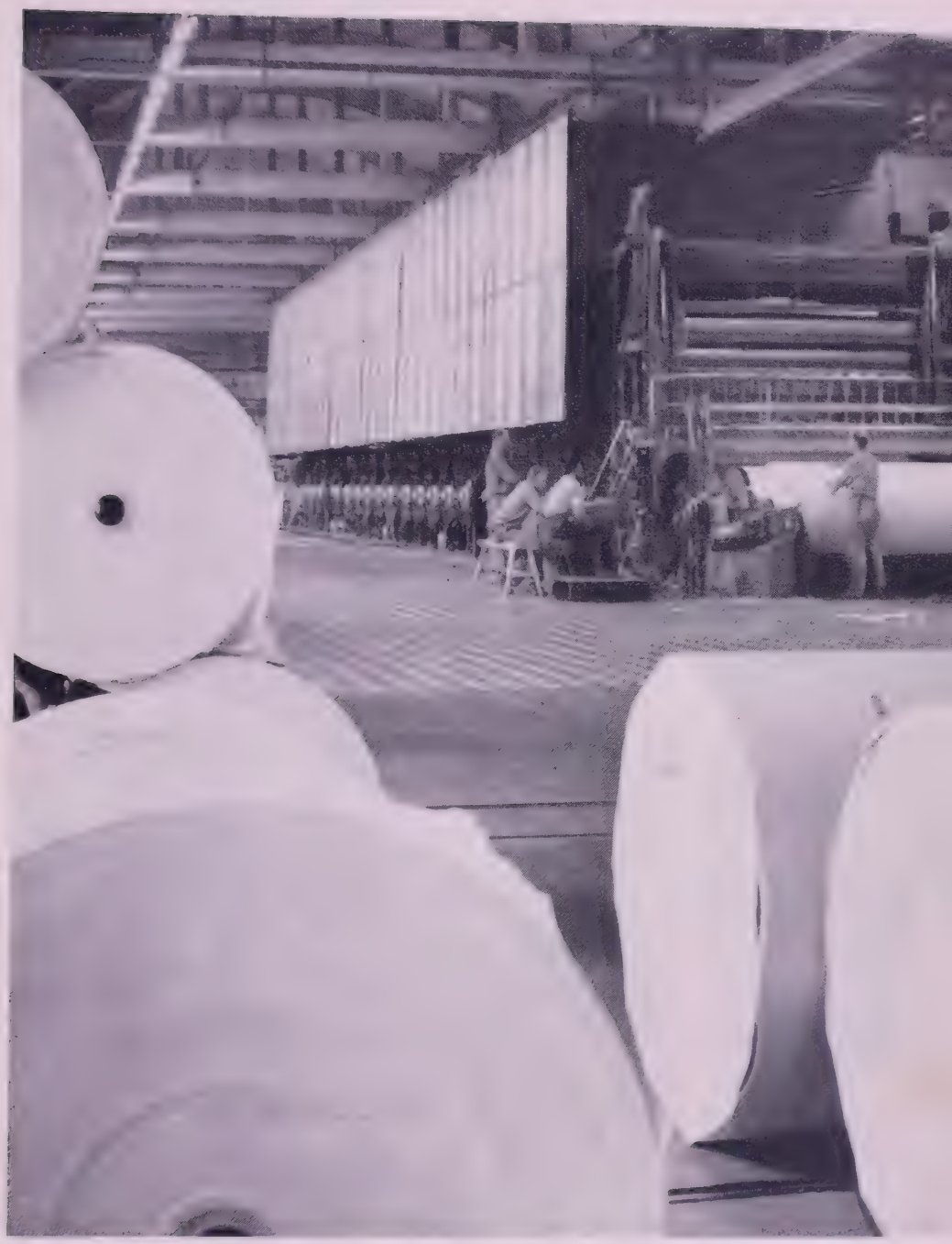


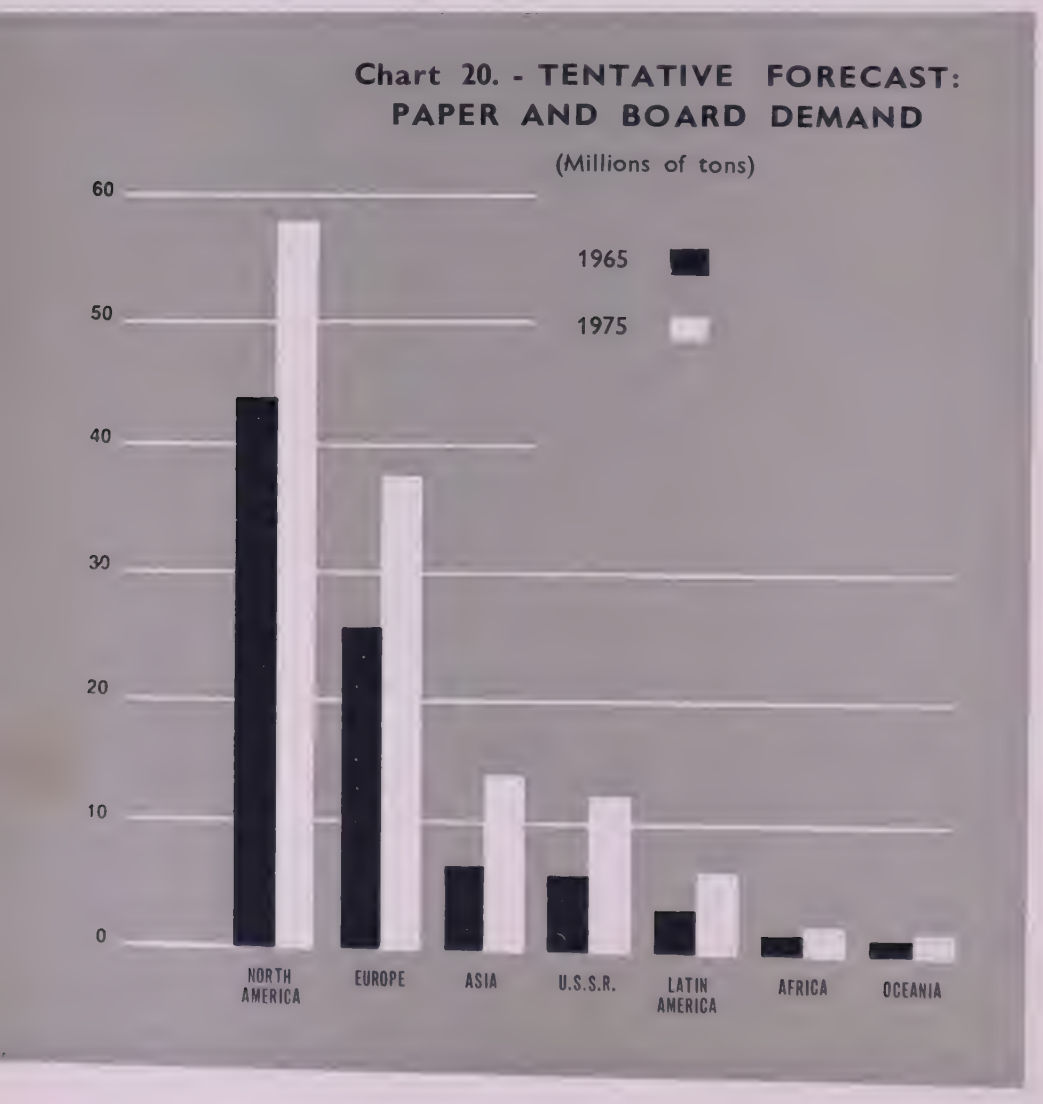
FIGURE 30. – Better utilization of the forest crop. There is a direct relationship between the consumption of printing and writing paper and newsprint on the one hand, and economic, social, educational and cultural development on the other. In 1959, it was estimated that world consumption of paper board would more than double by 1975.

(Courtesy Metsälütto)

than the total volume of recorded removals from all forests. There is thus considerable scope for increasing the output of wood products by reducing still further the amount of wood that goes to waste in various ways, as well as the proportion of the total cut used as fuelwood.

Significance of forestry in relation to food production

Through the greater part of his history man has obtained his food from the forest — game and seeds, fruit, berries, roots, etc. Still today, wild fruit, seeds and game are the staple diet of many people



in remote areas. In several countries of central Africa, like the Congo and Cameroon, game is supplying nearly half of the total production of animal proteins, and for the Congo this represents over 100,000 tons of meat.

Both for early man and for contemporary primitive tribes, however, the forest was and is more than a reservoir of food. The skins of sable, fox and bear provided clothing. The forest gave shelter from wind, rain and sun, and protection from enemies. Wood as a material was used for a variety of purposes, including construction, but its main use was as fuel — to give warmth and light, and for cooking purposes.

For primitive man, the forest was the basis of his existence; he had no apparent cause to destroy it. Yet recent research has shown that the practice of reducing the forest area by fire and by tree-girdling must have been widespread long before shifting cultivation came into being. This may have been to facilitate hunting or the digging of roots, or the object may have been to kill, and dry wood for fuel. Sometimes these inroads may have been self-healing, even facilitating the development of tree vegetation. But often they must have resulted in pushing forward permanently the boundaries of steppes, prairies and savannas.

In view of the present expanding world economy, forest products, which are a vital productive asset of life, have assumed an ever-increasing importance. In many parts of the world, even where prevailing living standards are low, the demand for wood is far in excess of the existing supply. In Asia, Africa and Latin America, where the majority of the population rely on wood as their only source of fuel, and must continue to do so until new sources of energy are developed, the most pressing need is fuelwood. Indeed, many thousand tons of cow dung, which could be used to increase the production of food, are burned every year in Asia for lack of other fuel. New supplies of fuelwood will be needed not only to stop this wasteful practice but also to take care of the tremendous upsurge of population numbers over the next decades. In south Asia only, 40 million cubic meters of fuelwood will be needed in 1975 over and above present consumption to take care of population increase alone, and about five times as much if wood were to be substituted for cow dung.

It has been said that timber-starved mankind needs forests to provide for some of the basic needs of civilized life. Paradoxically, however, such requirements in forest products hardly ever compete with the food requirements of man, and the clearing of forests for farming purposes is often a self-defeating practice.

In fact, the preservation or restoration of an adequate forest cover is a vital necessity for the protection of farmland against erosion and flooding and for the regulation of the water supply on which the growth of food crops depends. Indeed, excessive deforestation has led, and still is leading, to serious losses of farmland in many parts of the world. In Morocco, for instance, it is estimated that 40,000 hectares of farmland are destroyed every year by erosion, and this is by no means an isolated example.

One of the basic ways to increase farm production is the extension of irrigation. This involves expensive public works, yet this outlay may be wasted due to the silting of reservoirs and canals. If an irrigation scheme is to be a permanent asset in a country's farming, then the catchment area from which it derives its water must be protected from erosion by an adequate forest cover. In the United States, reafforestation of the drainage area of Lake MacMillan has reduced the rate of silting from over 10 cubic meters to under 1 cubic meter of silt per 500 square kilometers of the drainage area. Thus when mountain land is deforested for farming purposes, not only is the land so "gained" soon carried away by wind and water, but the expenditure and efforts spent on irrigation in neighboring lands are also made useless.

In irrigated cropping, too, tree plantations are an invaluable asset, thanks to the protection they afford against wind erosion, desiccation and seepage. For example, it has been calculated in Iraq that drainage costs may be lowered by as much as 20 percent by reducing the rate of seepage through the plantation of trees along canals.

These are some of the indirect ways in which forestry helps food production. There are direct ways too. In cultivated areas, the plantation of windbreaks and shelterbelts, which take up a negligible percentage of the cropland, can increase yields by 10 to 20 percent in favorable years, and from next to nothing to a normal yield in drought years; they represent an insurance which, after the first establishment expenditure, costs nothing, since the cost of maintenance is offset by

the products of thinning and the sacrifice of cropland is more than offset by the increase in yields.

As well as giving shelter, trees can provide valuable fodder, which is especially important when grazing animals must be reduced in number on the mountains because of the destruction they cause to the natural vegetation.

In arid climates, the plantation of forest trees may even be more than an insurance against bad harvests; it may be the only way of keeping a given tract of land in production. For instance, the great Indian desert is marching eastward, absorbing about 800 square kilometers of cropland every year. Protective plantations are the only effective defense against such desert encroachment. The same is true of sand dunes, which, unless they are fixed by a good vegetative cover, gradually advance on neighboring lands.

A number of food products can also be obtained from wood. During the digestion of wood for the production of cellulose by the sulfite process, part of the carbohydrates of the wood substance is dissolved. The sugars can be, and are being, used commercially for the production of fodder yeast. In the case of national emergencies, the nutritional value of all the carbohydrates of wood have been used on a very large scale as fodder cellulose for cattle feed. Sugar production from wood has hitherto not been undertaken on a commercial scale. Research which has been carried out in many countries in recent years has, however, resulted in better techniques, so that prospects for the economic feasibility have improved. Final success would mean that wood residues now wasted could be turned into sugars — dextrose and xylose — thus making a contribution toward raising the level of nutrition.

Summing up

Are the world's forests capable of meeting the increasing demands which further economic growth will impose upon them? There can be no doubt of their capacity to furnish these requirements. Even if we omit from calculation the forest area presently classified as inaccessible and the 1,300 million hectares of accessible forests not yet under exploitation, there is ample evidence to show that the 1,500

million hectares of forests already in use are capable of satisfying this demand.

It must not be supposed, however, that potential forestry output can be realized without special efforts. Intensive forestry production requires on the one hand heavy investment, both in labor and materials, and an adequate supply of professional skills. On the other hand, the rise in forest consciousness and in understanding of the multiple role of the forest, both by governments and by lay people, has not been confined to the developed regions only.

7. CONCLUSIONS: RESOURCES IN RELATION TO NEEDS

It is clear that the *world* potentials for increasing food production are very substantial indeed. If now we should attempt to confront the question as to what prospect there is that food production can be increased rapidly enough to provide a minimum satisfactory diet for the greater part of the world's population by, say, the year 2000, we must return to the regional approach. In brief, it does not serve much purpose to attempt to answer such a question on a global basis. It is unlikely that imports of food from the wealthier to the less wealthy regions can ever provide more than a small part of the needs. This would still remain true even if commercial imports were supplemented by substantial grants-in-aid through free distribution of surplus foodstuffs. It is therefore necessary to examine this question region by region.

For Europe, North America and Oceania, there can be no doubt. A glance at Chart 3 shows how production is soaring away from population in Europe. Production would be rising even faster if it were not for marketing difficulties. Throughout most of Europe, dietary levels are fairly satisfactory and population is expected to grow only by a modest 36 percent by 2000, or 50 percent if we include the U.S.S.R.

In the United States-Canada and Australia-New Zealand regions, present production capacity is considerably in excess of output. Even though production has been held down, huge stocks of surpluses have piled up, especially in North America. Resources, or future production capacity, are certainly capable of taking care of any probable requirements, with capacity to spare.

When one turns to the four underdeveloped regions, there is room for question.

In Latin America and Africa, the physical resources are unquestionably ample, without approaching their full utilization, to meet

the estimated increases required. There is good reason to believe that the more affluent parts of the world are ready and willing to give both the technical and financial assistance which may be needed to build up and supplement internal resources in these fields. The outcome will depend primarily upon the establishment of progressive and stable governments that are willing and able to mobilize their own resources and make effective use of foreign aid. The rate of resource destruction in some parts of Africa is, however, cause for considerable concern, and gives urgency to the " properly co-ordinated survey and appraisal of the land and water resources of Africa, in order to determine sound patterns of land use and population distribution " referred to above.

In the Near East, an increase in production in excess of threefold would push utilization of resources much closer to the limits set by present technical knowledge than would be the case in either Latin America or Africa. Quite apart from the political, administrative and institutional problems involved, it is an area in which there may be cause for some disquiet from the point of view of the natural resources. Water is strictly the limiting factor, and the two main river systems, the Nile and the Tigris-Euphrates, are already fairly fully drawn upon. Of course, all this might be changed by the desalinization of sea water at costs which would be economic for irrigation, though transportation costs to areas far removed from the coast could still remain a problem.

The need for a more than fourfold increase in food production in the Far East definitely raises the question of the adequacy of the basic physical resources. In the above-mentioned study of the Lower Ganges-Brahmaputra basin, a careful examination of resource potentialities led to the tentative conclusion that production could be increased about fourfold in this area. This is, however, an area where unutilized potential is probably substantially above average for the region, because a large part of the area can be brought under perennial irrigation, and present crop and livestock yields are low even by the standards of southern Asia. It is true that the levels of production per hectare envisaged in this study do not represent any absolute standard but they would constitute a fairly effective mobilization of the natural resources and present technical knowledge.

There is reason to believe, then, that in the Far East the balance between future food needs and known potentialities for production

may well prove to be delicate. If so, this is a region in which it is becoming a matter of some urgency to study *in fondo* the future potentials for food production in relation to needs and to determine the patterns of land and water utilization that would enable the maximum benefit to be derived from the scarce resources. If governments go about their task of planning agricultural development, armed with a clear and realistic knowledge of the feasible goals, the chances of bringing about a better balance between needs and production before it is too late will be considerably enhanced.

In conclusion, it may be said that the existence of large untapped resources of nature and knowledge represents a challenge to the ability and good will of man to solve a problem which is capable of solution. It does not, however, constitute any guarantee of success and least of all a cause for satisfaction with our current rate of progress.

It seems probable that a sustained and satisfactory rate of progress will require the allocation of appreciably greater resources for the education of peoples, for research, for physical investment and for international leadership and co-ordination than the nations of the world are making available at present. It will also require a greater willingness to move toward the institutional changes which would provide a more generally favorable climate for productive investment and application of technology.

It is for these reasons that the Director-General of FAO has launched the Freedom from Hunger Campaign.

Statistical appendix

TABLE 1. – AREA UNDER VARIOUS TYPES OF LAND USE

(Summary by continents and world)[1]

Continent	Total area [2]	Agricultural area		Forested land [5]	Other land [6]
		Arable land [3] and land under permanent crops	Permanent [4] meadows and pastures		
	Thousand hectares				
Europe (excl. U.S.S.R.)	493 000	153 000	78 000	138 000	124 000
U.S.S.R.	2 240 300	221 366	369 689	880 317	768 928
N. and C. America	2 426 000	256 000	364 000	824 000	982 000
South America	1 776 000	73 000	292 000	908 000	503 000
Asia (excl. Mainland China)	1 739 000	329 000	243 000	439 000	728 000
China, Mainland	976 101	109 354	177 996	76 600	612 151
Africa	3 027 000	239 000	598 000	727 000	1 463 000
Oceania	854 000	28 000	447 000	53 000	326 000
World total	13 531 000	1 409 000	2 569 000	4 046 000	5 507 000

SOURCE: FAO. *Production Yearbook 1961*, Vol. 15.

[1] Continental and world totals derived from available data; in the majority of cases, these data refer to 1958, 1959, or 1960, depending on the individual country.

[2] Total area refers to the total area of the country, including inland water bodies.

[3] Arable land (including fallow) and land under permanent crops includes land planted to crops (double-cropped areas counted only once), land temporarily fallow, temporary meadows for mowing or pasture, garden land, and area under fruit trees, vines, fruit-bearing shrubs, and rubber plantations.

[4] Permanent meadows and pastures refers to land under herbaceous forage crops, other than rotation grasses and clovers. In terms of the actual data classified under it, "permanent meadows and pastures" remains loosely defined because of the indefinite dividing line between this category and (*a*) temporary meadows, usually included under arable land; and (*b*) pastures (producing some wood from scattered trees and from shrubs) often included under forests.

[5] Forests and woodlands includes all lands with natural or planted stands of trees of present or potential value. The question of savannas, desert scrubs, second growths, and mixed lands raises the same problem as under item 4.

[6] Includes: (*a*) unused but potentially productive land; in most cases, this is subjectively determined by the reporting governments and represents anything from land being presently reclaimed to land which may in the future be put to agricultural use or be used for forests; (*b*) built-on area, wasteland and other land occupied by buildings, roads or lanes, barren land, inland water bodies, and any other land not specifically listed.

TABLE 2. – HARVESTED AREA OF MAJOR CROPS

(Summary by continents and world)

Crop	Europe (excl. U.S.S.R.)		N. and C. America		South America		Asia (excl. Mainland China)		Africa		Oceania		World	
	1948/49-1952/53	1958/59-1960/61	1948/49-1952/53	1958/59-1960/61	1948/49-1952/53	1958/59-1960/61	1948/49-1952/53	1958/59-1960/61	1948/49-1952/53	1958/59-1960/61	1948/49-1952/53	1958/59-1960/61	1948/49-1952/53	1958/59-1960/61
	Million hectares													
Wheat	28.0	29.1	38.9	31.1	6.9	7.5	25.8	34.4	6.0	7.3	4.7	4.9	169.8	202.8
Rye	12.2	10.9	1.2	0.9	0.8	1.1	0.5	0.7	—	—	—	—	38.1	30.6
Barley	8.9	11.3	7.2	9.5	1.0	1.4	9.7	11.3	5.2	5.3	0.5	1.1	52.0	61.5
Oats	12.5	10.0	20.0	16.2	0.8	1.0	0.5	0.6	0.4	0.6	0.9	1.4	53.7	45.8
Maize	10.3	11.5	39.4	40.0	8.3	11.7	8.7	11.8	10.2	11.6	0.1	0.1	91.0	105.0
Millet and sorghum	0.2	0.1	3.3	6.8	0.3	0.9	35.5	38.3	20.4	22.4	0.1	0.1	91.1	98.9
Rice, paddy	0.3	0.3	1.1	1.2	2.4	3.6	69.2	78.0	2.7	2.9	—	—	102.5	117.4
Total cereals [1]	72.4	73.2	111.1	105.7	20.5	26.5	149.9	175.1	44.9	50.1	6.3	7.6	598.2	661.9
Potatoes	9.5	9.2	0.9	0.8	0.9	1.0	0.9	1.2	0.2	0.2	0.1	0.1	23.0	25.3
Sweet potatoes and yams	—	—	0.4	0.3	0.2	0.2	1.4	1.6	2.4	—	—	—	10.1	15.8
Total pulses [2]	5.6	5.5	2.3	2.7	2.7	3.4	16.0	20.8	3.0	3.0	—	—	39.1	44.8
Total oilseeds [3]	2.9	2.6	19.0	19.6	6.2	7.2	21.9	28.2	7.5	9.2	—	—	83.5	96.6
Cotton	0.4	0.5	10.6	6.7	3.4	3.7	8.0	10.7	3.2	3.8	—	—	31.9	33.2

SOURCE: FAO. *Production Yearbook 1961*, Vol. 15.

NOTE: The world totals include data for the *U.S.S.R.* for the following crops: wheat, rye, barley, oats, maize, millet and sorghum rice, dry beans, dry peas, lentils, vetch, other pulses, soybeans, cottonseed, linseed, sunflowerseed, potatoes, cotton lint.

The world totals include data for *Mainland China* for the following crops: wheat, barley, oats, maize, millet and sorghum, rice, dry beans, dry peas, dry broad beans, soybeans, groundnuts, cottonseed, linseed, rapeseed, sesameseed, sunflowerseed, potatoes, sweet potatoes and yams, cotton lint.

[1] Wheat, rye, barley, oats, maize, millet and sorghum, rice.

[2] Dry beans, dry peas, dry broad beans, chick peas, lentils.

[3] Soybeans, groundnuts, cottonseed, linseed, rapeseed, sesame, sunflowerseed.

TABLE 3. – PRODUCTION OF MAJOR CROPS
(Summary by continents and world)

Crop	Europe (excl. U.S.S.R.)		N. and C. America		South America		Asia (excl. Mainland China)		Africa		Oceania		World	
	1948/49-1952/53	1958/59-1960/61	1948/49-1952/53	1958/59-1960/61	1948/49-1952/53	1958/59-1960/61	1948/49-1952/53	1958/59-1960/61	1948/49-1952/53	1958/59-1960/61	1948/49-1952/53	1958/59-1960/61	1948/49-1952/53	1958/59-1960/61
	Million metric tons													
Wheat	41.2	53.3	45.1	48.5	7.4	8.0	21.3	29.7	4.3	5.4	5.3	6.4	169.6	249.5
Rye	17.8	18.6	1.0	1.0	0.6	0.8	0.5	0.7	—	—	—	—	37.7	37.5
Barley	15.0	25.7	10.3	14.8	1.1	1.6	9.8	11.8	3.4	3.1	0.6	1.3	59.0	87.4
Oats	20.0	18.2	25.3	24.0	0.9	1.1	0.5	0.7	0.3	0.2	0.6	1.3	62.1	60.8
Maize	12.8	23.7	87.0	111.4	10.4	15.3	6.9	11.6	8.5	11.4	0.1	0.2	146.0	213.8
Millet and sorghum	0.2	0.1	4.1	15.3	0.2	1.4	14.1	17.7	12.0	14.2	0.1	0.2	46.5	70.1
Rice, paddy	1.3	1.6	2.5	3.3	4.1	6.3	97.2	130.9	3.4	4.3	0.1	0.1	164.7	231.0
Total cereals [1]	108.3	141.2	175.3	218.2	24.7	34.4	150.3	202.6	31.9	38.5	6.8	9.6	685.6	950.1
Sugar														
centrifugal, raw	7.8	12.3	12.2	15.0	3.3	6.2	3.4	6.9	1.6	2.6	1.0	1.6	32.3	52.2
noncentrifugal, cane	—	—	0.3	0.3	1.1	0.9	4.0	5.5	—	—	—	—	5.9	7.2
Potatoes	130.2	135.6	13.0	13.9	4.6	6.0	7.8	11.4	1.0	1.4	0.6	0.7	246.0	282.5
Sweet potatoes and yams	0.2	0.2	1.8	1.7	1.6	1.9	12.7	16.0	16.9	...	0.1	...	69.9	121.9
Total pulses [2]	2.6	2.7	1.5	2.0	1.9	2.4	7.7	10.6	1.8	1.8	—	—	23.5	27.9
Total oilseeds [3]	1.9	2.3	15.4	23.7	3.2	4.0	9.3	13.1	4.2	6.0	—	—	51.1	76.3
Cotton	—	—	3.4	3.4	0.6	0.7	1.1	1.6	0.7	0.9	—	—	7.6	10.6

SOURCE: FAO. *Production Yearbook 1961*, Vol. 15.
NOTE: The world totals include data for the *U.S.S.R.* for the following crops: wheat, rye, barley, oats, maize, millet and sorghum, rice, dry beans, dry peas, lentils, vetch, other pulses, soybeans, cottonseed, linseed, sunflowerseed, potatoes, cotton lint, sugar (centrifugal, raw).

The world totals include data for *Mainland China* for the following crops: wheat, barley, oats, maize, millet and sorghum, rice, dry beans, dry peas, dry broad beans, soybeans, groundnuts, cottonseed, linseed, rapeseed, sesameseed, sunflowerseed, potatoes, sweet potatoes and yams, cotton lint, sugar (centrifugal raw; noncentrifugal, cane).

[1] Wheat, rye, barley, oats, maize, millet and sorghum, rice.
[2] Dry beans, dry peas, dry broad beans, chick peas, lentils.
[3] Soybeans, groundnuts, cottonseed, linseed, rapeseed, sesame, sunflowerseed.

TABLE 4. – AVERAGE YIELD OF MAJOR CROPS

(Summary by continents and world)

Crop	Europe (excl. U.S.S.R.)		N. and C. America		South America		Asia (excl. Mainland China)		Africa		Oceania		World	
	1948/49-1952/53	1958/59-1960/61	1948/49-1952/53	1958/59-1960/61	1948/49-1952/53	1958/59-1960/61	1948/49-1952/53	1958/59-1960/61	1948/49-1952/53	1958/59-1960/61	1948/49-1952/53	1958/59-1960/61	1948/49-1952/53	1958/59-1960/61
	100 kilograms per hectare													
Wheat	14.7	18.3	11.6	15.6	10.8	10.6	8.3	8.7	7.1	7.3	11.3	13.0	10.0	12.3
Rye	14.7	17.1	8.0	11.1	7.4	7.6	9.8	10.6	4.1	...	4.8	...	9.9	12.2
Barley	16.9	22.7	14.3	15.5	11.3	11.2	10.1	10.4	6.5	5.9	12.1	12.4	11.3	14.2
Oats	16.0	18.2	12.7	14.9	10.7	10.5	10.4	12.3	6.9	3.8	7.1	9.0	11.6	13.3
Maize	12.4	20.5	22.1	27.8	12.5	13.8	7.9	9.2	8.4	9.8	18.0	22.8	16.0	20.3
Millet and sorghum	8.0	12.1	12.5	22.6	7.7	14.9	4.0	4.6	5.9	6.3	12.8	17.0	5.1	7.1
Rice, paddy	42.6	4.5	22.1	27.5	17.1	17.8	13.9	16.8	12.2	14.7	31.7	40.5	16.1	19.7
Potatoes	138.0	148.1	147.7	184.3	53.0	62.8	82.6	95.7	60.0	84.8	96.7	142.2	107.0	111.5
Sweet potatoes and yams	146.7	122.1	45.5	53.8	75.0	86.4	94.3	103.1	69.1	...	11.0	...	69.2	77.4
Cotton	1.5	3.0	3.2	5.1	1.8	2.0	1.3	1.5	2.1	2.4	1.8	1.5	2.4	3.2

SOURCE: FAO. *Production Yearbook 1961*, Vol. 15.

NOTE: Data for the *U.S.S.R.* and *Mainland China* are included in the world totals of all crops, except sweet potatoes and yams for the U.S.S.R., and rye for Mainland China.

TABLE 5. – NUMBERS OF MAJOR SPECIES OF LIVESTOCK
(Summary by continents and world)

Species	Europe (excl. U.S.S.R.)		U.S.S.R.		N. and C. America		South America		Asia (incl. Mainland China)		Africa		Oceania		World total	
	1958/59	1959/60	1958/59	1959/60	1958/59	1959/60	1958/59	1959/60	1958/59	1959/60	1958/59	1959/60	1958/59	1959/60	1958/59	1959/60
	Million head															
Horses	13.6	12.9	11.5	11.0	9.9	9.8	17.0	17.0	14.2	14.0	3.3	3.3	0.8	0.8	70.3	68.8
Mules	2.0	2.0	...	...	4.1	4.1	5.1	5.3	2.9	2.9	1.8	1.8	—	—	15.9	16.1
Asses	2.7	2.7	0.8	...	3.7	3.7	3.8	4.0	18.4	18.4	10.4	10.5	—	—	39.8	40.1
Cattle	110.7	113.3	70.8	74.2	138.6	142.3	153.8	158.0	277.9	277.7	109.8	111.1	22.5	22.8	884.1	899.4
Pigs	101.7	105.1	48.7	53.4	81.3	80.5	57.5	59.5	194.5	215.6	4.3	4.3	2.2	2.3	490.2	520.7
Sheep	133.3	134.2	129.9	136.1	40.9	41.5	121.3	120.0	212.3	216.2	135.7	137.9	199.6	202.3	973.0	988.2
Goats	16.8	16.3	9.3	7.9	16.9	16.9	24.9	25.2	178.8	178.9	9.23	94.5	0.2	0.2	339.5	339.9
Buffaloes	0.5	0.5	—	—	—	—	—	—	92.1	91.6	1.8	1.8	0.1	—	94.5	94.0
Camels	—	—	0.3	0.3	—	—	—	—	3.1	2.9	7.1	7.1	—	—	10.5	10.3

SOURCE: FAO. *Production Yearbook 1961*, Vol. 15.

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